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Great saving of labour. No noise. No dust. No dirt. Ashes discharged 20 ft. clear of vessel.—Apply, F. J. TREWENT & PROCTOR, LTD., Naval Architects and Surveyors, 43, Billiter Bldgs., Billiter St., London, E.C. Od 4335

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See Advertisement page 77.

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See Advertisement, page 27. 1872

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See Advertisement page 56, March 7. 2402

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and SALES MANAGEMENT.—Write for brochure describing our special Course of Training for posts of unlimited scope in this lucrative field.—DIRECTOR, Institute of Engineering Salesmanship, 333, Oxford Road, Manchester. 1679

TENDERS.

THE GREAT INDIAN PENINSULA RAILWAY COMPANY, 48, COPTHALL AVENUE, LONDON, E.C.2, invite

Tenders for :—

1.	STEELWORK for Bridges ...	Fee £1.
2.	STEELWORK for Bridges (Four 30 ft. Deck Spans)	,, 7s. 6d.
3.	CAST-IRON WATER PIPES, &c.	,, 2s. 6d.
4.	DRAWN or EXTRUDED BRASS STRIPS	,, 2s. 6d.
5.	SPARE PARTS of Carriages and Wagons	,, 10s.
6.	Miscellaneous Articles and Materials	,, 7s. 6d.

Tenders are due by Eleven a.m., on 25th March, 1924. Tender Forms obtainable at above address. Fees not returnable. D 200

COUNTY BOROUGH OF WOLVERHAMPTON.

WATERWORKS UNDERTAKING.

15 in. and 12 in. CAST IRON TRUNK MAINS.

The Wolverhampton Corporation is prepared to receive

Tenders for Providing and

LAYING about 5400 yards of 15 in. and 2940 yards of 12 in. CAST IRON WATER MAINS, and Executing other Work in connection therewith, from Contractors who pay to the whole of their employees such remuneration and observe such hours of employment as are recognised by the Employees' Unions and Associations of Employers in the several localities where the work is done.

A copy of the Specification, Quantities, and Form of Tender may be obtained from Mr. E. A. B. WOODWARD, Waterworks Engineer, Town Hall, Wolverhampton, upon payment of the sum of £2 sterling, which amount will be returned to each Contractor who submits a *bona fide* Tender, but not otherwise.

Each Tender must be enclosed in a sealed envelope, addressed to "The Chairman of the Water Committee," and endorsed "Trunk Mains," and delivered at my Office on or before Ten a.m. on Tuesday the 15th day of April, 1924.

The right to decline the lowest or any Tender is reserved to the Corporation.

F. E. WARBRICK HOWELL,
Town Clerk.

Town Hall, Wolverhampton.
5th March, 1924. D 178

METROPOLITAN WATER BOARD.

MAIN.—KEMPTON TO CRICKLEWOOD.

TENDER FOR SECTION NO. 1—LAYING AND JOINTING 48 in. CAST IRON AND 52 in. STEEL PIPES AND CONTINGENT WORKS FROM KEMPTON TO GREENFORD.

The Metropolitan Water Board invite

Tenders for the Laying and

JOINTING of about 7¼ miles of 48 in. diameter CAST IRON WATER MAIN and the laying of about 450 yds. of 52 in. STEEL PIPES in subways, between the Board's works at Kempton and Windmill Lane, north of Greenford Valve House in the County of Middlesex.

Drawings, Conditions of Contract and Specifications may be inspected without payment of a fee at the Offices of the Board, Chief Engineer's Department (Room 201) on and after 20th March, 1924.

Forms of Tender, Conditions of Contract, Specification, Bills of Quantities and Schedules of Prices, together with drawings and a spare copy of the Bills of Quantities and Schedules of prices, may be obtained on and after 31st March, 1924, from Mr. HENRY E. STILGOE, M.Inst.C.E., the Chief Engineer, on production of an official receipt for the sum of £20, which sum must be deposited with the Accountant to the Board, and will be returned on receipt of a *bona fide* Tender, accompanied by all the above-named documents and drawings (with the exception of the spare copy of the Bills of Quantities and Schedules of Prices which may be retained by the Tenderer). Such payments and applications must be made between the hours of Ten a.m. and 4.30 p.m. (Saturdays Ten a.m. and Twelve noon).

Cheques must be made payable to the "Metropolitan Water Board," and not to individuals.

Tenders enclosed in sealed envelopes, addressed to "The Clerk of the Board, Metropolitan Water Board, New River Head, Clerkenwell, E.C. 1," and endorsed "Tender for Section No. 1, Kempton to Cricklewood Main," must be delivered at the Offices of the Board not later than Ten a.m. on Monday, 28th April, 1924.

The Board do not bind themselves to accept the lowest or any Tender.

G. F. STRINGER,
Clerk of the Board.

Offices of the Board,
New River Head,
Clerkenwell, E.C. 1.
8th March, 1924. D 177

DREDGER.

THE LEE CONSERVANCY BOARD invite

Tenders, Designs and

Specifications for a STEAM LADDER BUCKET DREDGER, 80 feet long by 15 feet Beam, depth middle line 4 ft. 6 ins. draught not to exceed 3 feet, to dredge to a depth of 12 feet and raise not less than 65 tons per hour, to load into barges 4 ft. 6 ins. above water-line and to be forward cutting to cut its own flotation. The framing and gear to be easily lowered so as to pass under bridges 6 ft. 9 ins. above water-line. The hull to be of Steel to Lloyd's Specification, with accommodation for two men to sleep on board. State time of delivery afloat ready for work on the Lee Navigation at Bromley Lock, Bow, London, E.

The Board do not bind themselves to accept the lowest or any Tender, and all designs offered are to be at the expense of the persons tendering. Tenders, Designs and Specifications, giving full particulars, to be delivered in sealed envelopes, marked "Dredger," not later than March 26th, 1924, to :—

CHARLES N. TWEEN, M.Inst.C.E.,
Engineer and Manager to the Board,
Enfield Lock, Middlesex. D 133

METROPOLITAN WATER BOARD.

TENDERS FOR THE RECONSTRUCTION AND PAINTING OF THE CRYSTAL PALACE TANK AND STRUCTURE, SYDENHAM HILL, S.E.

The Metropolitan Water Board invite

Tenders for the Reconstruc-

TION of the IRON TRUSSES, etc., and the PAINTING of the CRYSTAL PALACE TANK and STRUCTURE, Sydenham Hill, London, S.E.

Forms of Tender, Conditions of Contract, Specification and Drawings, may be obtained on and after Friday, 21st March, 1924, at the Offices of the Board, Chief Engineer's Department, on production of an official receipt for the sum of £2 2s., which sum must be deposited with the Accountant to the Board and will be returned on receipt of a *bona fide* Tender with all incidental documents and drawings. Such payments and applications must be made between the hours of Ten a.m and 4.30 p.m. (Saturdays Ten a.m. and Twelve noon.)

Cheques must be made payable to the "Metropolitan Water Board" and not to individuals.

Tenders, enclosed in sealed envelopes, addressed to "The Clerk of the Board, Metropolitan Water Board, New River Head, Clerkenwell, E.C. 1," and endorsed "Tender for Reconstruction Crystal Palace Tank," must be delivered at the Offices of the Board not later than Ten a.m on Tuesday, 15th April, 1924.

The Board do not bind themselves to accept the lowest or any Tender.

G. F. STRINGER.
Clerk of the Board.

Offices of the Board,
New River Head,
Clerkenwell, E.C. 1.
11th March, 1924. D 191

APPOINTMENTS OPEN.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH.

An Assistant for

Experimental Work in connection with timber-drying kilns is REQUIRED for the FOREST PRODUCTS RESEARCH BOARD. Candidates should be engineers with a knowledge of mathematics and physics and should be honours graduates or possess equivalent qualifications. They should have practical experience in engineering.

Preference will be given, other things being equal, to ex-service men.

Salary £350 per annum, inclusive.

Applications, giving particulars of age, qualifications, military service, etc., with copies of testimonials and/or names of referees, should be made in writing not later than 20th March to THE SECRETARY, Department of Scientific and Industrial Research, 16, Old Queen Street, S.W.1. D 183

Manager Wanted, to Take

Charge of Shops in large Ship-repairing Establishment in North of England. Must be thoroughly practical, good organiser and have considerable experience of modern practice in shops dealing with all classes of work, including foundry. State experience, age, and salary required.—Address, D 181, Offices of ENGINEERING.

ADMINISTRATIVE COUNTY OF LONDON.

The London County Council invites

Applications from Men under

28 years of age for a POSITION of TECHNICAL ASSISTANT on the permanent staff in the inspection branch of the department of the Chief Officer of the Fire Brigade. The commencing salary will be £165 a year, rising by annual increments of £15 a year to £240, with the possibility of promotion on the occurrence of a vacancy. The salary is based on pre-war conditions and is subject at present to temporary additions on the Civil Service Scale, fluctuating according to the cost of living. The total commencing remuneration is, on the present basis, £265 4s. 7d. a year. The next revision of the temporary additions will take place not later than 1st September, 1924.

Candidates should either have taken a course in mechanical and electrical engineering at a recognised training college and possess the appropriate certificates or diplomas, or should have received in some other way a good theoretical and practical training. They should be capable of writing lucid reports on inspections, etc. Some experience in a commercial undertaking, or in engineering works under commercial conditions, would be an additional qualification.

Members of the Council's staff may apply.

Due weight will be given to the claims of those candidates who served or attempted to serve with H.M. Forces during the Great War. Candidates who did not so serve must be natural born British subjects.

Apply for forms (containing full details) to the Clerk of the Council, The County Hall, Westminster Bridge, S.E.1. Stamped addressed foolscap envelope necessary. Forms must be returned not later than Eleven a.m., on Thursday, 3rd April, 1924. Canvassing disqualifies.

JAMES BIRD, D 206
Clerk of the London County Council.

The Royal Air Force

REQUIRES ELECTRICIANS, WIRELESS OPERATORS and POWER STATION TRADESMEN. Age limits: ex-service men 18 to 30; non ex-service 18 to 26. Pay from 24s. 6d. to 38s. 6d. per week on enlistment, and all found. Allowance for wife and children to men 26 and over. —Write, stating age, or call :—INSPECTOR OF RECRUITING, R.A.F., 4, Henrietta Street, Covent Garden, London, W.C.2. C 965

Electric Power Supply Engi-

neers.—Applicants are informed that the Senior position advertised on January 11th, under BOX No. C 535, has been filled. D 162

THE YORKSHIRE ELECTRIC POWER COMPANY.

SALES ENGINEER.

Applications are Invited for

the POSITION of SALES ENGINEER. The gentleman appointed will be required to take full charge of the Company's Sales Department.

Applicants must be well qualified by previous engineering and commercial experience.

Communications marked "Sales Engineer" should be addressed to the Company, at 36, Park Place, Leeds. D 138

BELFAST HARBOUR.

The Belfast Harbour Commissioners require the

Services of a Temporary

ASSISTANT ENGINEER having experience of Harbour constructional work.

Applicants should be Corporate Members of the Institution of Civil Engineers, and be accustomed to measuring up and setting out works, and be prepared to make examinations by diving.

The salary will be after the rate of £33 per month, and further information as to the duties involved can be obtained from the undersigned, to whom applications, accompanied by copies of not more than three recent testimonials, should be addressed and sent in on or before Wednesday, the 26th March, 1924.

T. S. GILBERT, M.Inst.C.E.,
Engineer-in-Chief.

Harbour Office,
Belfast. D 188

Messrs. Merz & McLellan,

Consulting Engineers, of 32, Victoria Street, London, S.W., REQUIRE the SERVICES of a QUALIFIED ELECTRICAL and MECHANICAL ENGINEER, age about 28-32, for a position which may develop into one of some responsibility. Salary will be dependent upon qualifications, of which the following are essential: good general (rather than specialized) knowledge and ability to express himself clearly and concisely. The position would suit a University Graduate who has served his apprenticeship and spent a few years abroad. None but written applications will be considered. D 182

Applications Invited from

One or Two Keen well-educated YOUNG ENGINEERS, with practical and theoretical training, capable of handling contracts, and ultimately to take charge of branch offices.

Special knowledge of piping of all kinds desirable. State age, experience and salary required.—Address, D 197, Offices of ENGINEERING.

District Engineer

REQUIRED by the GOVERNMENT of PALESTINE for the RAILWAY DEPARTMENT, for three years' service with prospect of permanency. Salary £E600, rising by annual increments of £E25 to £E750 a year. Expatriation allowance of £E50 a year, plus a variable cost of living allowance, at present 5%, based on fixed minimum pay of appointment plus an additional amount of £E27 a year. Free first-class passages. Candidates, aged 30 to 35, preferably single, must have had not less than five years' experience on British Railways on maintenance and construction work. Should be an A.M.I.C.E.—Apply at once in writing, stating age, whether married or single, and giving brief details of qualifications and experience, to the CROWN AGENTS FOR THE COLONIES, 4, Millbank, London, S.W.1, quoting at the top of application M/1/484. D 207

Required in large Steel Works

in Lincolnshire, ENGINEERING FOREMAN experienced in Maintenance and Repairs in Rolling Mills, Steel Furnace Plant and Boilers. —Address, stating age, experience and salary required, together with copies of references, D 179, Offices of ENGINEERING.

Heating Engineer.—Draughts-

MAN REQUIRED for London Office must have had a good training and experience in all business relative to Central Heating, Hot Water Supplies, Ventilation, etc.—Address, stating fully all qualifications, age and salary required, all communications will be treated as strictly confidential, D 176, Offices of ENGINEERING.

Wanted, Thoroughly

Experienced DRAUGHTSMAN for design and shop drawings of Bridgework and general Steelwork to Engineers' specifications. State age, experience and salary required.—Address, D 153, Offices of ENGINEERING.

Reliable Draughtsman

REQUIRED, preferably with general mechanical design. Must have had experience in plant lay-out, and good mathematician. Works near London.—Address, stating age, experience, and salary required, D 174, Offices of ENGINEERING.

Wanted by a Firm of Well-

known Brewers' Engineers, CAPABLE DRAUGHTSMAN, experienced in Brewing, Malting and Chemical Work, accustomed to take own measurements, ordering material, and supervising erection. State age, previous experience, and salary required.—Address, D 173, Offices of ENGINEERING.

Leading Designer Wante

by large firm of reinforced concrete engineers. Must be fully experienced. State full particulars and salary required.—Address, D 194, Offices of ENGINEERING.

Estimators, with Experience

in pipe work design, modern power station, WANTED, Immediately for London Office.—Apply stating age, experience and salary required, to D 205, Offices of ENGINEERING.

Designer Required for Steam

Turbines. Must have had good experience in Drawing Office and Works and fully qualified to make turbine calculations. Apply in writing, stating age, qualifications, positions held and salary expected.—Address, D 195, Offices of ENGINEERING.

Draughtsman, Good Qualified

man. Used to structural steelwork and screening plants.—Apply, stating full particulars to BOX F, W. H. SMITH & SON, 53, Lichfield Street, Wolverhampton. D 19

Senior Locomotive

DRAUGHTSMAN REQUIRED for Crown Agents' Drawing Office. Candidate must have been trained in Railway Workshops or with locomotive builders, and must possess sound practical and theoretical knowledge of locomotive practice.

Commencing salary, £253 to £300 per annum (plus bonus), according to the ability of the candidate selected. (The present bonus on £250 is £127 and on £300 is £140.)—Applicant should not be over 35 years of age, and should forward full particulars of education and technical qualifications to THE CHIEF ENGINEER (DESIGNS), CROWN AGENTS FOR THE COLONIES, 4, Millbank, Westminster, S.W.1. D 16

Draughtsman, Used to

Refrigeration work, for London district. State age, experience, and salary required.—Address, D 165, Offices of ENGINEERING.

Draughtsman (Temporary)

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Engineer, 28, General Mech-

anical training. Specialising in Diesel and Semi-Diesel Engines for Marine work, DESIRES a Permanent and Progressive POSITION with Shipping firm running large Diesel-Engined ships, as an Efficiency Engineer, or with a firm of Marine Diesel builders as Manager or Assist. Manager Diesel Department. Would go first voyages with new ships so fitted, as Supervising Engineer, etc.—Address, D 171, Offices of ENGINEERING.

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THE HARTEBEESTPOORT DAM.

THE Hartebeestpoort Dam which has recently been completed near Pretoria, South Africa, and of which we give illustrations on the present page and pages 324, 325 and 328, forms part of a scheme which has been under consideration for many years. Some structure of the kind was originally suggested in connection with the water supply of Pretoria, but this lead to nothing. In 1905 the possibility of impounding water on the Crocodile River at this point was taken up by the Transvaal Irrigation Department, and the following years were occupied with the drafting of a provisional irrigation scheme with a dam in the Hartebeestpoort as its main feature.

Fig. 1. HARTEBEESTPOORT DAM.

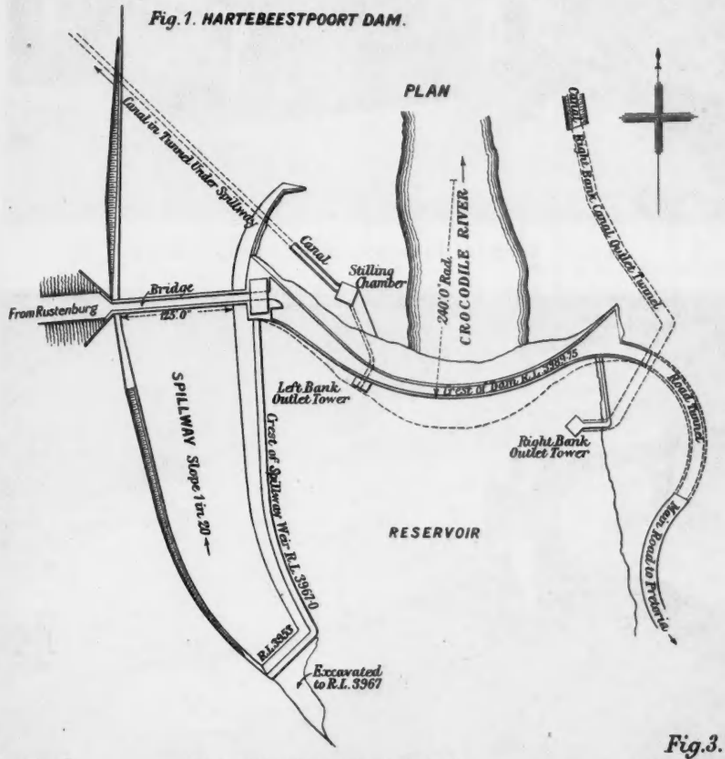


Fig. 2. **SECTIONAL ELEVATION OF DAM.**

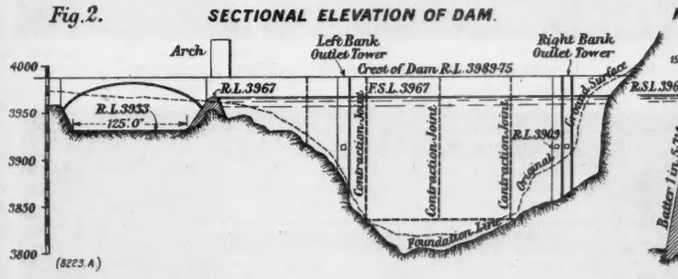
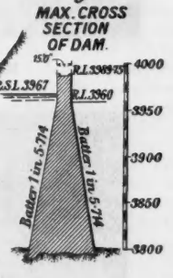


Fig. 3. **MAX. CROSS SECTION OF DAM.**



No more definite action was, however, taken for some time, and it was not till some years after the Union that anything further was done. Public opinion on the subject gathering weight, legislation was put through in 1913–14 dealing with a scheme for which a Select Committee thought more information necessary. The war supervened before any actual work had been embarked upon, and further progress was delayed until 1918, except in the matter of the purchase of land, &c.

The area embraced in the scheme lies west and north-west of Pretoria. Due west of this city runs the Magaliesberg range, which at a distance of about 23 miles from Pretoria is traversed in an almost north and south line by the Hartebeestpoort, through which flows the Crocodile River, joined just south of the "poort" by the Magalies River. The mountains run east and west and the fall is, through the range, from south to north, the gathering ground embracing a large tract of country between the Magliesburg and the Witwatersrand. This area is about 1,560 sq. miles, part of which is dolomite which furnishes a regular supply to areas already irrigated. The area which will be served by the scheme is about 7 miles to the north of the range, and is traversed by the railway running from Pretoria to Rustenburg. The main road between these two places has been submerged by the reservoir and has been diverted, and is now carried over the top of the dam. A new railway under construction from Pretoria and along the Magalies River passes not far to the south of the dam site.

The land to be irrigated is in the Pretoria and Rustenburg districts, and it is expected that in the first instance it will be possible to supply about 32,000 acres with water. The actual area commanded is, however, considerably greater, and much additional land may be ultimately supplied. The districts are excellent. The soil is rich, and tobacco and fruit and other crops are raised on a considerable scale. The climate is healthy, the mean maximum of three summer months being 89 degrees, and the mean minimum for three winter months 42 degrees. Frosts are infrequent. The Government is now considering the reports of experts on the types of farming most suitable for irrigation in the area, and what scheme of land allotment or settlement shall be adopted, having regard to transport facilities, marketing, &c.

The rainfall is greatest between October and March, the wettest month being January with a mean rainfall of 4·99 in. The minimum fall is in the month of June when the records show a mean of only 0·06 in. Water is most needed in the spring months of August, September and October. Gaugings at the dam site indicate a very great range of run-off of the gathering ground. In some years the results show for the twelve months a total of 1,614 million cub. ft., as in 1913–14, while other years are above 30,000 million cub. ft. For instance, the records for 1908–1909 show 30,246 million cub. ft., and those for 1917–18 no less than 38,406 million cub. ft., the maximum for any one month having been 13,659 million cub. ft., for January, 1909. The mean over the period of about eighteen years for which records are available, is 8,308 million cub. ft. for the year. According to Act of Parliament 600 million cub. ft. must be passed down-stream as compensation water per annum.

The dam which has been constructed in the "poort" has a height from lowest foundation to crest level of waste weir of 172 ft. The approximate high flood level to which the impounded water can be raised under rights already acquired, is put at 22 ft. above this, the top of the solid parapet wall being again 1 ft. 9 in. higher still, giving a total maximum height for the concrete wall of 194·75 ft. For the present it is intended to work the reservoir to the level of the waste weir, but this has been designed so that, should future needs require it, it will be possible to arrange movable gates on the waste weir to take advantage of the additional height permitted by the structure of the dam itself. The lowest foundations were carried down 32 ft. below the river bed level at the site. The outlet sills are placed 82 ft. above the river bed level, but the section is so narrow at the bottom that less than 10 per cent. of the gross storage is sacrificed by this plan, which was adopted in order to get a good fall for the irrigation water for which the canals have to be taken through gaps between hills.

To the spillway level the dam impounds 5,936 million cub. ft., so that well over 5,000 million cub. ft. are available. Under these conditions the submerged area will be about 6·7 sq. miles, while if in the future the highest level permissible is adopted the area of the resulting reservoir will be 9·2 sq. miles.

The original design was for a straight gravity section dam which would have involved a greatest width at foundations of 140 ft. When it was decided to expedite the work and make it serve the purpose of reducing unemployment among the white population, it was decided to abandon the original plan and to redesign the dam as an arch structure, by which means the concrete work was reduced to a thickness of 73 ft. at its lowest point. This enabled the foundations to be placed in one season, after which the work was advanced very rapidly so that it was virtually completed in about two years from the time construction was seriously commenced.

The alteration of design, however, had other consequences, and it is stated that if the change had been decided upon earlier it is quite possible another site higher up would have been selected. As it is the dam abuts on the east side against a steep wall of sound rock, while the west abutment is not nearly so satisfactory. This will be evident from the drawings we give in Figs. 1 and 2, and the views which also illustrate this article, some of which have been placed at our service by Mr. A. D. Lewis, M.Inst.C.E., Director of Irrigation, who has been responsible for this work since 1921, when he succeeded Mr. F. E. Kanthack, who was director from 1910 till 1920. On the west side the ground flattens out considerably, in addition to which the rock has proved to be lacking in cohesion. On the east the rock is firm and sound and was well suited for use as aggregate for the necessary concrete. The main features of the design will be seen from Fig. 2 to be the arch dam, which in plan is laid out on circular arcs and transition curves, and a long spillway at right angles to the direction of the dam with a spillway channel outside it spanned at one point by a bridge carrying the Pretoria-Rustenburg road.

The two views given in Figs. 4 and 5, page 324, show the dam as it appears from above, from the two banks, *i.e.*, looking respectively towards, in Fig. 5, the west abutment, and Fig. 4, towards the east abutment. A very good general view from down stream is shown in Fig. 12, on page 338. This shows up clearly the steep scarp on the east side

and the flatter ground on the west, and indicates the graceful appearance of the bridge over the spillway, to the right of the view. The characteristics of the two abutments are also well shown in Figs. 14 and 15, the latter showing the solid rock into which the arch wall is bonded, and incidentally, above, the entrance to the road tunnel, shown also in Fig. 4 and referred to below. Fig. 13, on page 338, is a view of the spillway.

Dealing first with the dam proper, a section of which is given in Fig. 3, at the lowest foundation level (3,795 ft. M.S.L.), the curvature of the arch was laid out to a radius of 148 ft. for the up-stream face, and 75 ft. for the down-stream face. From this point upwards, as will be noted in Fig. 3, both faces taper inwards to a batter of 1 in 5·714. This continues to the 3,960-ft. level, above which, for the remaining portion of 15 ft. width, both faces are vertical, the upper face being struck to a radius of 240 ft. Four radial contraction joints are provided at intervals of 64 ft. to 78 ft. above the 3,835 ft. level, as shown in Fig. 2. The maximum stress in the concrete varies according to different formulae from 13·3 tons per square foot to 14·9 tons per square foot, assuming pure arch action. By a formula attributed to Craeger in which the effect on the arch of restraint at the base is taken into consideration, the maximum stress works out at 19·4 tons per square foot.

As previously stated, the abutment on the west side was not altogether satisfactory, and this end of the work was made especially massive in order to withstand satisfactorily the thrust of the arch. The treatment will be clear from Figs. 5 and 14, while the addition of the massive ornamental arch, shown in Fig. 6, at the same end, and the spillway, assist the dam arch on this side.

The weir has a total length of 421 ft. 6 in., and as stated, its crest level is at 3,967 ft. Water flows over it at right angles to the line of the main stream channel, into a sloping trough, falling at the rate of 1 in. 20, and increasing in width from 56 ft. at its up-stream end, to 125 ft. at the bridge in line with the dam. It is well seen in Fig. 5, and again in Fig. 13, page 338. At its upper end the floor of the spillway is 14 ft. below the crest of the weir. It is of concrete and is reinforced under the bridge. The floor is 3 ft. thick on the side near the weir, and diminishes to 1 ft. 6 in. on the side remote from the latter. On the side opposite the weir the spillway is finished with a low concrete wall which is heightened in the neighbourhood of the bridge. Below the bridge, as will be clear from the drawings and the views Figs. 5 and 14, the trough opens out considerably and is finished with a wide apron covering the cliff. Beyond this gunite protection for the cliff face has been adopted and carried down for about 50 ft. below the weir crest level.

The reservoir is intended to serve areas on both sides of the Crocodile River, and two outlet towers are provided for regulating purposes. The tower for controlling the supply to the west bank is built against the up-stream face of the dam, as will be clear from Figs. 4 and 5. That for the east bank is an isolated structure connected to the bank by means of a light foot-bridge. Provision is made for discharging the greater quantity to the east bank, the channel on this side being of 300 cusecs. capacity, with 19 cusecs. for compensation water. On the west bank the channel has only a capacity of 150 cusecs. The tower for the east bank is fitted with four 30-in. gate valves, arranged in pairs on opposite faces of the rectangular structure. On leaving the reservoir the water passes at once into a tunnel through the hillside, about 400 ft. in length, after which it flows in an open channel.

On the west side the tower has a roller sluice, 5 ft. in diameter, provided as an emergency valve. The outlet at this point takes the form of a belled 5-ft. diameter pipe embedded in the concrete. This on the down-stream side divides into three pipes, the inner being controlled by a 30-in. gate valve, and the outer two by 24 in. diameter gate valves. The discharge is directed against reinforced concrete walls in a stilling chamber, from which the water flows into an open channel for a few yards, when it enters a tunnel passing under the spillway apron, as indicated in Fig. 1. The stilling chamber is enclosed in the small rectangular building shown in the foreground of Fig. 14; beyond this may be seen

THE HARTEBEESTPOORT DAM; SOUTH AFRICA.

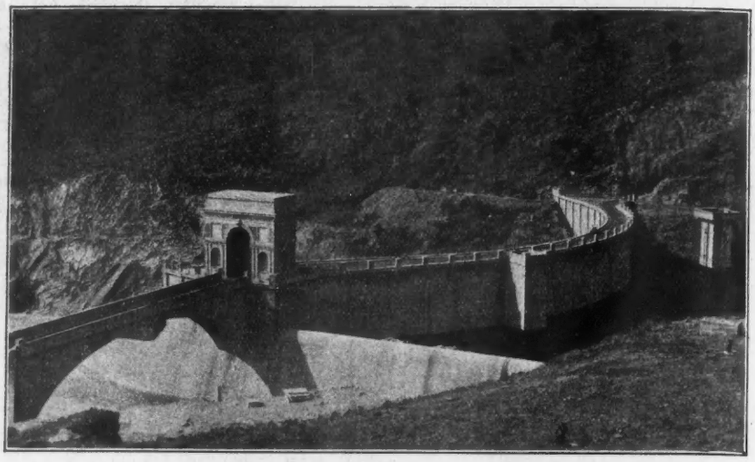


FIG. 4. UPSTREAM FACE LOOKING TOWARDS EAST BANK.

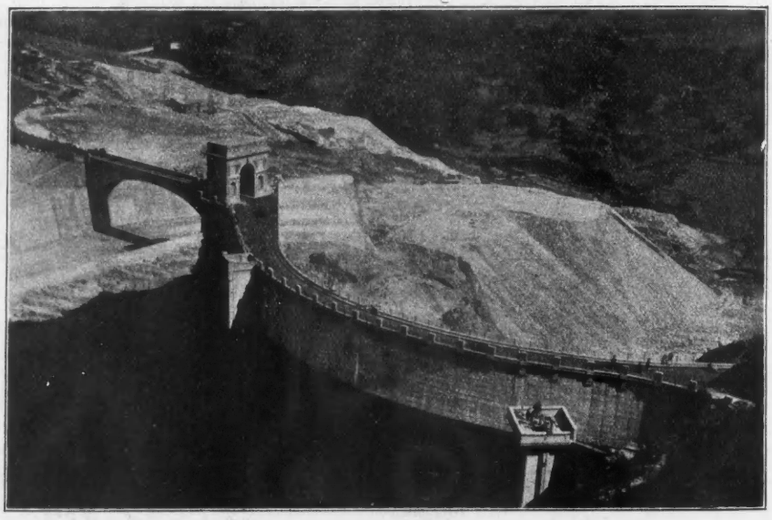


FIG. 5. UPSTREAM FACE LOOKING TOWARDS WEST ABUTMENT.

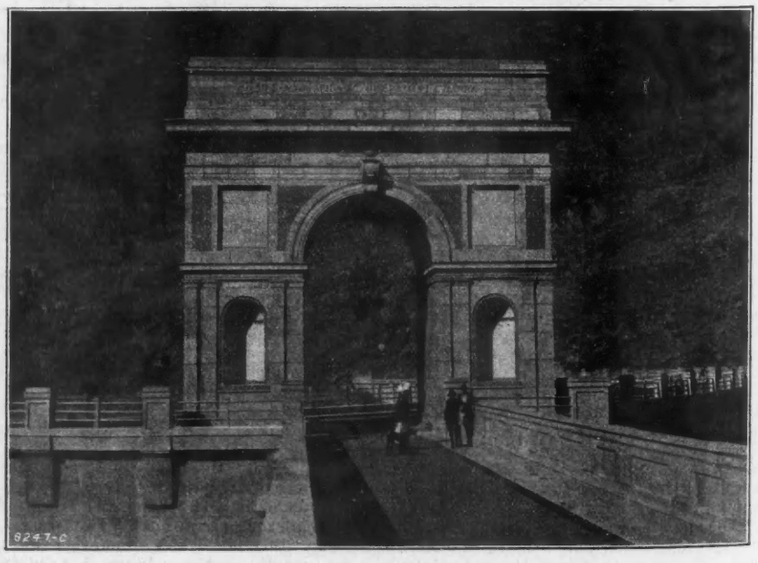


FIG. 6. ARCH ON WEST ABUTMENT.

5-FT. ROLLER SLUICE VALVE FOR THE HARTEBEESTPOORT DAM.

CONSTRUCTED BY MESSRS. GLENFIELD AND KENNEDY, LIMITED, ENGINEERS, KILMARNOCK.

Fig. 7.

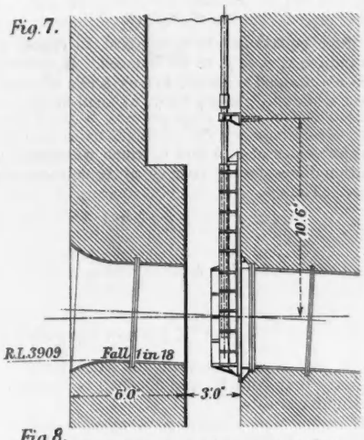


Fig. 8.

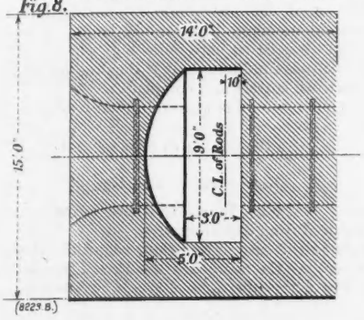


Fig. 9. ROLLER SLUICE FOR MEDIUM HEADS. HAARTEBEESTPOORT DAM SLUICE.

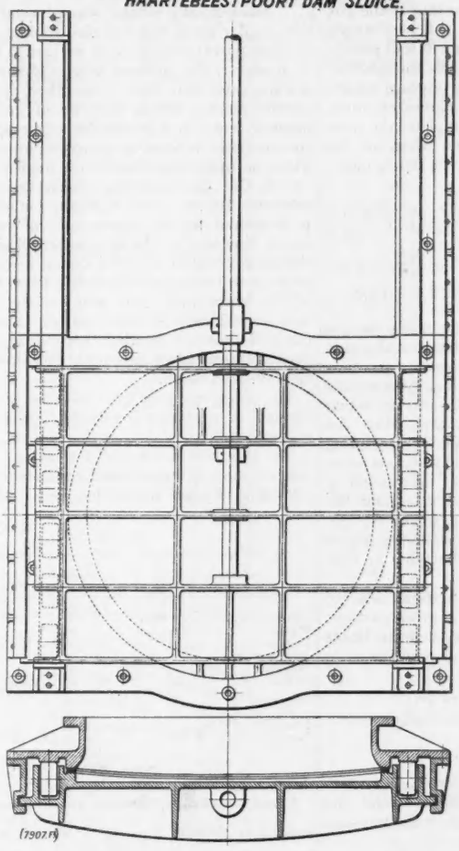


Fig. 10.

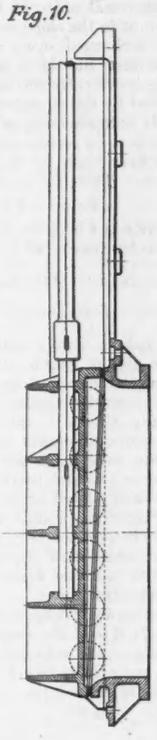


Fig. 11.

the short length of open canal, then the mouth of the tunnel under the spillway, and in Fig. 5 the channel beyond the latter.

The 5-ft. roller sluice illustrated, with its setting, in Figs. 7 to 11, was supplied by Messrs. Glenfield and Kennedy, Limited, of Kilmarnock, and it is to the courtesy of Mr. E. Bruce Ball, of this firm, that we are indebted for the privilege of reproducing the views of the dam appearing in Figs. 12 to 15, on page 338. The 5-ft. sluice in this case works under a head of about 71 ft., on a series of fixed anti-friction rollers. The faces of the valve and seating are set at a slight angle from the perpendicular, the effect of which is that as soon as vertical movement of the valve takes place the faces separate. When closing, as soon as the faces come in contact movement is arrested, and cutting due to sliding avoided. The sluice is fitted with a two-speed hand-head gear, which allows a low speed to be used when the faces are nearly in contact and a higher speed for the more open position, when the load on the valve is smaller.

The road bridge over the spillway has a clear span of 141 ft. 6 in. It is of reinforced concrete. The plan in Fig. 1 shows how the road approaches and is carried over the dam. The road length on the dam proper is 163 yards, with an added 49 yards for the spillway bridge and abutment. On the eastern side the dam is approached by the road carried along a ledge cut in the hillside, and sweeping on to the curved dam by means of a tunnel about 175 ft. long cut through the hill. On the west side the road is in the open, as will be seen in Fig. 5. The deviation required by the submergence of the old route necessitated the construction of about 6 miles of new road. Passing places for traffic are arranged at both abutments of the dam, and elsewhere in the approaches. The ornamental arch, of which a view is given in Fig. 6, is designed on the proportions of the Arc de Triomphe, in Paris. It is 41 ft. high, and as already stated its weight contributes to the stability of the dam abutment on the west bank.

As regards construction, work was commenced at the site soon after the war. A railway was laid down, roads and quarters were built, and work on cofferdams for the diversion of the river was begun. In 1921–22 the original plans were altered as already stated, thereby considerably reducing the amount of concrete work required, and the cost. The cofferdams were finally closed after the flood season ending in May, 1921, and excavation was pushed ahead so that concrete in the foundations was first laid on July 29. As a result of the modification in design, two months later the work had been raised 6 ft. above the river bed, and subsequently rapid progress was made. The floods of the 1922–23 season were impounded, and the dam was virtually completed by the end of March of the latter year. In September the road over the top of the dam was opened for traffic, and nothing remained to be completed save the installation of a small hydro-electric plant for use in providing electric lighting. From the placing of the foundations, water has been allowed to rise continuously, and recently was reported to be only 14 ft. below the spillway level.

The material used for the concrete was in the case of the coarse aggregate, quartzite procured from the east bank. The material on the west side was too friable to be serviceable. Ample supplies of sand were obtained from the river bed below the site.

THE PRINCIPLE OF DYNAMICAL SIMILARITY, WITH SPECIAL REFERENCE TO MODEL EXPERIMENTS.

By Professor A. H. GIBSON, D.Sc., M.Inst.C.E.

1. IF all the forces acting on a moving body, or on a particle of fluid in motion are known, its state as regards position, velocity, and acceleration at any time can be determined from a solution of the equations of motion, and conversely, if the state of motion is known, the force necessary to produce this state may be calculated.

In many engineering problems, however, the forces involved are so complex that it is impossible even to state them in simple mathematical terms, much less to obtain a mathematical solution of the problem, and this is especially the case where the forces are due to fluid motion. Thus in such problems as those involving the resistance of floating vessels, airships, or aeroplanes, and the forces called into play during their manœuvres; the characteristics of screw propellers and of turbine runners and pump impellers of complex form, mathematical analysis, based on first principles is incapable of giving a solution, and this can only be obtained by direct experiment.

Owing to the inconvenience and to the great cost of full-scale experiments, much attention has been directed in recent years to the use of small-scale models, geometrically similar to their originals. The use of models to deduce the resistance of projected ships has been long established, and every confidence is placed in the results of such model experiments. The field of aeronautics is one which lends itself particularly to this form of investigation, and model experiments on the stability and resistance of aeroplanes, have given results of great value which could not be obtained in any other way.

At the same time it is important to emphasise the fact that a scale model only reproduces the behaviour of its original when the conditions of operation are truly similar for both; that conditions which, without close examination appear to be similar, may lead to results which are very misleading; and that there are conditions under which such a model cannot be made to reproduce the behaviour of its prototype.

2. The conditions necessary for true similarity, and under which the behaviour of a model is a true copy of its original, may in general be deduced

from an application of the principles of "dimensional homogeneity," and "dynamical similarity."

The first of these states that all the terms of any correct physical equation must have the same dimensions. That is, if the numerical value of any one term in the equation depends on the size of one of the fundamental units, all the other terms must depend upon it in the same way, so that if the size of the unit is changed, every term will be changed in the same ratio, and the equation will still remain valid. This is evidently the case, since the relationship described by the equation is a physical reality which exists independently of the choice of units, so that if it is to be correct and complete, the facts which it defines must be the same whatever the units may be. Thus, for example, in the equation

$$S = v\,t + 1/2\,a\,t^2$$

for the position of a body having an initial velocity v and an acceleration a, all terms are of the same dimensions, since $v\,t$ is of the dimensions $\frac{\text{space}}{\text{time}} \times \text{time}$, while $a\,t^2$ is of dimensions $\frac{\text{velocity}}{\text{time}} \times (\text{time})^2 =$ space. It follows that whether the metre or the foot be the unit of length, and whatever the unit of time, the relationship is equally true.

Two geometrically similar moving systems are "dynamically similar" when all corresponding particles trace out similar paths, and when the velocities are such as to make all corresponding forces acting on two such particles, in the same ratio. The velocities so related, are termed "corresponding speeds." Since the product of the mass and the acceleration determines one of the forces on any particle, the ratio of all other corresponding forces acting on two particles must be the same as that of their acceleration forces.

3. In two geometrically similar systems denoted by (1) and (2), if w be the weight of a given particle, ρ the density, v the velocity, l any definite linear dimension, and r the radius of curvature of the path, these forces are in the ratio

$$\frac{F_1}{F_2} = \frac{w_1}{r_1}\cdot\frac{v_1^2}{r_2}\cdot\frac{r_2}{w_2}\cdot\frac{v_2^2}{r_1} = \frac{\rho_1 l_1^3}{\rho_2 l_2^3}\cdot\frac{r_2}{r_1}\left(\frac{v_1}{v_2}\right)^2 = \frac{\rho_1}{\rho_2}\left(\frac{l_1}{l_2}\frac{v_1}{v_2}\right)^2.$$

It follows that for dynamical similarity, the corresponding speeds must be such as to make the corresponding forces due to each one of the physical factors involved, proportional to $\rho\,l^2\,v^2$.

In the case of the relative motion of a solid surface and a fluid, if the only factor involved is the weight of the fluid, as is approximately the case in the flow of a liquid from an orifice under gravity, then since the force due to the weight is proportional to $\rho\,l^3$, the required condition will evidently be satisfied if

$$\frac{v_1}{v_2} = \sqrt{\frac{l_1}{l_2}}$$

On the other hand, if viscous forces are all important, since the force due to viscosity equals $\mu\frac{d\,v}{d\,l}$ per unit area, where μ is the coefficient of viscosity,

$$\frac{F_1}{F_2} = \frac{\mu_1}{\mu_2}\cdot\left(\frac{l_1}{l_2}\right)^2\cdot\frac{v_1}{v_2}\cdot\frac{l_2}{l_1} = \frac{\mu_1}{\mu_2}\frac{l_1}{l_2}\frac{v_1}{v_2}$$

and for this to equal $\frac{\rho_1}{\rho_2}\left(\frac{l_1}{l_2}\frac{v_1}{v_2}\right)^2$ it is necessary that

$$\frac{\rho_1 l_1 v_1}{\mu_1} = \frac{\rho_2 l_2 v_2}{\mu_2}$$

or that

$$\frac{v_1}{v_2} = \frac{\mu_1}{\mu_2}\frac{\rho_2}{\rho_1}\frac{l_2}{l_1} = \frac{\nu_1}{\nu_2}\frac{l_2}{l_1}$$

where ν is the "kinematic viscosity" μ/ρ.

Generally speaking, where the influence of gravity is involved in the interaction between a solid and a fluid, as is the case where surface waves or disturbances are produced, and where the direct influence of viscosity is negligibly small, corresponding speeds are proportional to the square roots of corresponding linear dimensions; while where gravitational forces are not involved, and where the forces are due to viscous resistances, corresponding speeds are inversely proportional to corresponding linear dimensions and directly proportional to the kinematic viscosities.

All surface wave and eddy phenomena are typical of the first type of interaction, while the resistance of an airship or of a submarine submerged to such a depth that no surface waves are produced, is an example of the second type.

The resistance of a surface vessel is one of a series of typical cases, of importance in practice, in which both gravity and viscosity are involved, and in which therefore no two corresponding speeds will satisfy all requirements. In other words the speeds which give geometrically similar wave formations around two similar ships will not give similar stream lines in those parts of the systems subject to viscous flow. If, however, the influence of one of these factors is much greater than that of the other, approximately similar results, which may be of great value in practice, can be obtained by using corresponding speeds chosen with reference to the important factor. Thus in tank experiments on models of floating vessels the corresponding speeds are chosen with reference to the wave and eddy effects, and are proportional to the square root of corresponding linear dimensions. In this, as in all similar cases, the approximation involves a scale error, which will be more or less serious depending upon the influence of the factor which has been tacitly ignored. In tank experiments a correction for this is made by the well-known "Froude" method, and the results thus obtained agree well with those obtained from the full-sized vessel.

The foregoing principles may be more generally applied to problems involving fluid resistance, as follows:—

The interaction between a solid and fluid during relative motion may depend upon some or all of the following physical quantities, and if the symbol F

TABLE I.

Quantity.	Symbol.	Dimensions.
Length	l	$[l]$
Time	t	$[t]$
Velocity	v	$[l\,t^{-1}]$
Acceleration	g	$[l\,t^{-2}]$
Density	ρ	$[M\,l^{-3}]$
Force	R = mass × accn.	$[M\,l\,t^{-2}]$
Viscosity	μ = stress × $\frac{l}{v}$	$[M\,l^{-1}\,t^{-1}]$
Elasticity of solid	E = stress	$[M\,l^{-1}\,t^{-2}]$
Compressibility of fluid	V_p = vel.* of sound waves in medium.	$[l\,t^{-1}]$

* Since the velocity of propagation of sound waves in an elastic medium is given by $V_p = \sqrt{\frac{K}{\rho}}$, where K is the modulus of compressibility, the compressibility may be defined in terms of V_p and of ρ.

denote some function, any physical relationship involving them may be expressed symbolically as

$$F(l, v, \rho, t, M, \&c.) = 0.$$

All these quantities may be defined in terms of three fundamental units. The most convenient units are usually M, l, t.

Suppose some physical relationship to involve only four quantities, say, R, l, v, ρ, of which three, viz., l, v, ρ, are mutually independent, in the form

$$R \propto l^x v^y \rho^z$$

Then, for this relationship to be generally true whatever units of mass, length, or time are used, the equation must be dimensionally homogeneous, and since a mass can only be equal to a mass, a length to a length, and a time to a time, these quantities must each be identical for both sides of the equation.

Expressing the equation dimensionally gives

$$M l^{-2} = l^x l^y t^{-y} M^z l^{-3z}$$

and, equating the indices of like quantities, we have

$$\left.\begin{aligned} 1 &= z \\ 1 &= x + y - 3z \\ -2 &= -y \end{aligned}\right\} \quad \text{whence } \begin{aligned} z &= 1 \\ y &= 2 \\ x &= 2 \end{aligned}$$

or

$$R \propto l^2 v^2 \rho$$

The quantity $\left[\frac{R}{l^2 v^2 \rho}\right]$ which may be denoted by $[K_1]$ is dimensionless. It is a numerical quantity whose value is the same whether the metrical or the foot-pound system of units is used.

Where only four quantities are involved, as in this case, the fact that there are three fundamental and mutually independent units, enables us to write down three simultaneous equations, from which the values of the indices x, y, z, necessary to satisfy the condition of dimensional homogeneity can be deduced.

If more than four quantities of different kinds are involved, for example, if

$$R \propto l^x v^y \rho^z \mu^p$$

the three equations are insufficient to enable the four indices x, y, z, p, to be deduced. If, however, R be maintained constant in any series of experiments, while l, v, ρ and μ vary, we shall have

$$\mu \propto l^a v^b \rho^c$$

and the values of a, b and c, which will make this equation dimensionally correct can be determined as before. Thus

$$M l^{-1} t^{-1} = l^a l^b t^{-b} M^c l^{-3c}$$

so that

$$\left.\begin{aligned} 1 &= c \\ -1 &= a + b - 3c \\ -1 &= -b \end{aligned}\right\} \quad \text{whence } \begin{aligned} c &= 1 \\ b &= 1 \\ a &= 1 \end{aligned}$$

and $\mu \propto l\,v\,\rho$

The quantity $\left[\frac{\mu}{l\,v\,\rho}\right]$ or $[K_2]$ is now dimensionless.

If R and μ may vary at the same time, it is necessary that both K_1 and K_2 shall be dimensionless simultaneously.

Extending this reasoning, it appears that if n quantities of different kinds are involved in any dynamical relationship, there will be $n - 3$ quantities [K] deduced as here indicated, which must be dimensionless simultaneously if the original relationship is to be correct and complete.

Any such general relationship then reduces to the form

$$\psi(K_1, K_2, K_3 \ldots K_{n-3}) = 1 \quad . \quad (1)$$

or

$$K_1 = \phi(K_2, K_3 \ldots K_{n-3}) . \quad . \quad (2)$$

where ψ and ϕ are functions whose forms can only be deduced from experiment.

Thus in the case in question, where the relationship involves the five quantities R, μ, l, v, ρ, so that $n - 3 = 2$, the equations

$$\psi\left(\frac{R}{l^2 v^2 \rho}\right)\left(\frac{\mu}{l\,v\,\rho}\right) = 1 \quad . \quad . \quad (3)$$

or

$$\psi\left(\frac{R}{l^2 v^2 \rho}\right)\left(\frac{\nu}{l\,v}\right) = 1$$

or

$$R = l^2 v^2 \rho\,\phi\left(\frac{\nu}{l\,v}\right) . \quad . \quad . \quad (4)$$

will represent the original relationship.

Whatever the form of the functions ψ and ϕ, it must be such that the values of $R/l^2 v^2 \rho$ and $\frac{\nu}{l v}$ are connected by a single relationship, which will be independent of the units of measurement, and will therefore apply equally well to a model and to the original of which it is a scale copy.

Since each of the terms of the above function is dimensionless, any function of such a term will also be dimensionless, and will be independent of the remaining quantities, so that any one may be replaced by a function of itself, or may be multiplied by a function of any other without affecting the truth of the equation.

For example, if the original relationship also involves a time t and an acceleration g, these introduce arguments K_3 and K_4, whose values may, as in the case of K_1 and K_2, be shown to equal $\frac{v\,t}{l}$ and $l\,g/v^2$, and equations (3) and (4) become

$$\psi\left(\frac{R}{l^2 v^2 \rho}\right)\left(\frac{\nu}{l\,v}\right)\left(\frac{v\,t}{l}\right)\left(\frac{l\,g}{v^2}\right) = 1 \quad . \quad . \quad (5)$$

$$R = l^2 v^2 \rho\,\phi\left(\frac{\nu}{l\,v}\right)\left(\frac{v\,t}{l}\right)\left(\frac{l\,g}{v^2}\right) \quad . \quad . \quad (6)$$

Then, if we multiply the second term of the function in (6) by the third, we get

$$R = l^2 v^2 \rho\,\phi\left(\frac{\nu}{l\,v}\right)\left(\frac{t\,g}{v}\right)\left(\frac{l\,g}{v^2}\right)$$

which is equally true.

The most general expression, involving the whole nine of the quantities specified in Table I, would be

$$\psi\left(\frac{R}{l^2 v^2 \rho}\right)\left(\frac{\nu}{l\,v}\right)\left(\frac{v\,t}{l}\right)\left(\frac{l\,g}{v^2}\right)\left(\frac{E}{\rho\,v^2}\right)\left(\frac{v}{V\rho}\right) = 1. \quad (7)$$

or

$$R = l^2 v^2 \rho\,\phi\left(\frac{\nu}{l\,v}\right)\left(\frac{v\,t}{l}\right)\left(\frac{l\,g}{v^2}\right)\left(\frac{E}{\rho\,v^2}\right)\left(\frac{v}{V\rho}\right) . \quad (8)$$

and for true dynamic similarity it is necessary that

each of the terms in this expression shall be dimensionless, *i.e.*, shall be the same for both original and model.

In the great majority of cases, however, the last two terms, involving the elasticity of the solid and the compressibility of the fluid, may be neglected. The elasticity term is only involved where the distortion of the body due to the forces is sufficient to modify the results appreciably. The last term is always negligible if the fluid is a liquid, while even if it is a gas it only becomes important in cases of resistance when the velocities approach the velocity of sound in the fluid. For velocities up to about 600 ft.-sec. it may in general be neglected.

Under these circumstances expression (5) indicates the conditions to be satisfied.

A number of typical examples of the use of this investigation will now be considered.

5. *Flow of Fluid Through Pipes.*—If changes in density are so small that compressibility may be neglected, the resistance will depend upon the size of pipe and upon v, ρ and μ, and if the flow is uniform, the general equation (3)

$$\psi\left(\frac{R}{d^2\,\rho\,v^2}\right)\left(\frac{\nu}{v\,d}\right) = 1$$

or

$$\psi\left(\frac{R}{d\,\rho\,v^2\,l}\right)\left(\frac{\nu}{v\,d}\right) = 1,$$

where d is the diameter, l the length, and R the total resistance to flow, represents the relationship.

This expression is equivalent to

$$R = d\,\rho\,v^2\,l\,\phi\left(\frac{\nu}{v\,d}\right),$$

and since $R = p\,\frac{\pi d^2}{4}$, where p is the difference of pressure at the two ends of the pipe,

$$\therefore\quad p = \frac{\rho\,v^2\,l}{d}\,\phi\left(\frac{\nu}{v\,d}\right) \qquad . \quad . \quad (9)$$

where the form of the function ϕ remains to be found from experiment. In the case of stream-line flow, experiment shows that p is proportional to v. It follows that $\phi\left(\frac{\nu}{v\,d}\right)$ must equal $\frac{k\,\nu}{v\,d}$, where k is some numerical constant, and therefore that

$$p = \frac{k\,\mu\,v}{d^2} \qquad . \quad . \quad . \quad . \quad (10)$$

If the flow is turbulent, the loss of head is approximately proportional to v^n, where n depends upon the roughness of the pipe, and usually lies between 1·75 and 2. In this case $\phi\left(\frac{\nu}{d\,v}\right)$ must be such as to make $\phi\left(\frac{1}{v}\right) = v^{n-2}$, so that

$$\phi\left(\frac{\nu}{d\,v}\right) \propto \left(\frac{\nu}{d\,v}\right)^{2-n}$$

and

$$p \propto \frac{\rho\,v^2\,l}{d}\left(\frac{\nu}{d\,v}\right)^{2-n}$$

$$= \frac{k'\,\rho\,v^n\,.\,\nu^{2-n}\,.\,l}{d^{3-n}}$$

or

$$h = \frac{k'\,v^n\,.\,\nu^{2-n}}{d^{3-n}}\,.\,l \qquad . \quad . \quad . \quad (11)$$

where h is the difference of head at the two ends of the pipe.

If the foregoing assumptions are correct, on plotting observed values of $\frac{p\,d}{\rho\,v^2\,l}$, against simultaneous values of $\frac{\nu}{v\,d}$ in a series of experiments in which different liquids or pipes of different diameters, are used, and in which the roughnesses of the surface are proportional to the diameters, the points should lie on a single curve. Numerous observers, notably Stanton and Pannell,* have shown that this is true for fluids as widely different as air, oil and water.

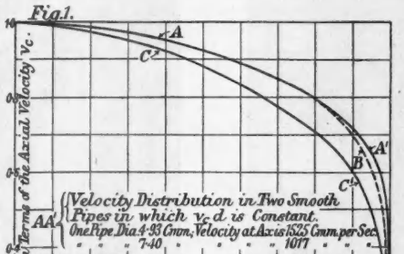
Equation (9) shows that with an incompressible fluid, if the resistance to flow varies as v^2, $\phi\left(\frac{\nu}{d\,v}\right)$ degenerates into a numerical constant. Viscosity ceases to have any direct influence on the resistance, and true similarity of flow should be obtained in all pipes at all velocities. If n is less than 2, the equations show that for similarity of flow in two pipes of different diameters, or conveying different fluids, it is necessary that $\frac{\nu}{v\,d}$ should be the same in both cases.

This has been shown to be true by Stanton, who measured the distribution of velocity with turbulent flow across the diameters of two rough pipes of different diameters and repeated the measurements for two smooth pipes. In the rough pipes ($n = 2$) the velocity distribution (CC′, Fig. 1) was the same in both pipes and at all velocities. In the smooth pipes ($n < 2$) identical curves were obtained only when $\frac{\nu}{v\,d}$ was the same in each pipe. Under other conditions the curves were sensibly identical from the centre up to a radius of about 0·8 times the radius of the pipe, but differed appreciably at larger radii. (AA′ and AB, Fig. 1.)

In any type of pipe the "critical velocity" at which the type of motion changes from stream-line to turbulent is obtained with a constant value of $\frac{\nu}{v\,d}$, and this is generally true for fluid motion under other circumstances.

Experiment shows that the assumption that the resistance to flow with turbulent motion in smooth pipes is proportional to some constant power of the

Fig. 1.



velocity is not strictly true. Thus Stanton* obtained the following results from measurements on a ½ in. smooth pipe :—

v cm. per sec. ..	58	258	900	2,250
n	1·72	1·77	1·82	1·92

Recent investigations indicate that a formula of the type

$$\frac{R}{\rho\,v^2} = a\left(\frac{\nu}{v\,d}\right)^a + b \qquad . \quad . \quad (11a)$$

more nearly fits the experimental results, and Dr. C. H. Lees,† from experiments by Stanton on smooth pipes of diameters ranging from 0·361cm. to 12·62 cm., has determined the values of a, a and b. Writing the formula as

$$\frac{h\,d}{4l\,v^2} = a\left(\frac{\nu}{v\,d}\right)^a + b \qquad . \quad . \quad (11b)$$

these values are $a = 0{\cdot}00801$; $a = 0{\cdot}35$; $b = 0{\cdot}000028$ in foot-second units.

If, over any small range of velocity, $R \propto v^n$, on differentiating expression (11a) with respect to v, it appears that

$$n = 2 - \frac{a}{1 + \frac{b}{a}\left(\frac{v\,d}{\nu}\right)^a}$$

so that, for a given velocity, n will increase with the diameter, just as, for a given diameter it increases with the velocity, ultimately approximating the value 2 when $v\,d$ is large.

It is to be noted, however, that true similarity of flow in two pipes of different diameters is only to be expected, even if $\div\, v\,d$ is the same for both, if the pipes themselves are geometrically similar, *i.e.*, if their roughnesses are proportional to their diameters. Thus a large concrete pipe whose roughness relatively to its diameter, is the same as that of Stanton's smooth brass pipes, would be expected to give results agreeing with equation (11b), whereas a large pipe of the same diameter, having a very smooth surface would probably have a lower resistance.*

(6) *Discharge over Weirs or through Orifices under Gravity.*—Assuming that the flow depends only on the head, the velocity, the density and viscosity of the fluid, the size of the orifice, and on gravity,

$$F(h, v, \rho, \mu, l, g) = 0$$

Taking h, v and ρ as independent variables, and proceeding in the usual way, we get

$$K_1 = \frac{l}{h};\ K_2 = \frac{\mu}{h\,\rho\,v} = \frac{\nu}{h\,v};\ K_3 = \frac{v^2}{g\,h}$$

$$\therefore\ \psi\left(\frac{l}{h}\right)\left(\frac{\nu}{h\,v}\right)\left(\frac{v^2}{g\,h}\right) = 1 \qquad . \quad (12)$$

If two weirs or orifices are similar and similarly situated, *i.e.*, with $h \propto l$, the first and last terms of the function will be identical for both if, as is shown to be very approximately the case by experiment, v is proportional to $\sqrt{h}$. For complete dynamical similarity it is also necessary that $\nu / h\,v$ or $\nu / h^{\frac{3}{2}}$ shall be the same for both, so that if the same fluid is being discharged in both, viscosity tends to prevent exact similarity of the streams. In order to obtain the same coefficients of discharge it would be necessary to use different fluids such that

$$\frac{\nu_1}{\nu_2} = \left(\frac{h_1}{h_2}\right)^{\frac{3}{2}} = \left(\frac{l_1}{l_2}\right)^{\frac{3}{2}}$$

Thus the same coefficient of discharge would be expected from a 1 in. orifice discharging water under a head of 1 ft. as from a 9 in. orifice discharging oil having a viscosity 27 times that of water, under a head of 9 ft. Writing $Q \propto v\,h^2$, expression (12) becomes

$$\psi\left(\frac{l}{h}\right)\left(\frac{\nu h}{Q}\right)\left(\frac{Q^2}{g\,h^5}\right) = 1$$

which can be reduced to

$$\psi\left(\frac{l}{h}\right)\left(\frac{\nu}{h^{\frac{5}{2}}\sqrt{g}}\right)\left(\frac{Q}{h^{\frac{5}{2}}\sqrt{g}}\right) = 1$$

so that, if $l \propto h$, we have

$$\frac{\nu}{h^{\frac{5}{2}}} = \phi\left(\frac{Q}{h^{\frac{5}{2}}}\right)$$

It follows that, on plotting values of $Q \div h^{\frac{5}{2}}$ against values of $h^{\frac{3}{2}} \div \nu$, all the points should lie on a single curve, whether obtained from a model or a full-sized weir or orifice. Since in such orifices

$$v = \sqrt{g\,h}\,\phi\left(\frac{\nu}{h\,v}\right)$$

it appears that v cannot be proportional to $\sqrt{h}$ if viscosity has any influence. Assuming $v \propto h^n$, and writing

$$v \propto \sqrt{h}\left(\frac{\nu}{h\,v}\right)^a$$

we have

$$v^{1+a} \propto h^{0{\cdot}5-a}\,\nu^a$$

$$\therefore\ v \propto h^{\frac{0{\cdot}5-a}{1+a}}\,\nu^{\frac{a}{1+a}}$$

$$\therefore\ n = \frac{0{\cdot}5-a}{1+a} \text{ and } \frac{a}{1+a} = \frac{1-2n}{3n};$$

from which

$$v \propto h^n\,\nu^{\frac{1-2n}{3n}}$$

and

$$Q \propto h^{2+n}\,\nu^{\frac{1-2n}{3n}}$$

for similar orifices. Thus experiments on a right-angled triangular weir† shows that $n = 0{\cdot}48$, and that with water at normal temperatures

$$Q = 2{\cdot}48\,h^{2{\cdot}43}\ \text{c.f.s.}$$

indicating that at different viscosities the discharge would be proportional to $\nu^{0{\cdot}028}$. In this case a 100 per cent. increase in the viscosity, such as would be obtained by altering the temperature from 90 deg. F. to 40 deg. F. would increase the discharge by 2·0 per cent.

(To be continued.)

* Phil. Trans. Roy. Soc. A., vol. ccxiv, 1914, page 199.

* N.P.L., Collected Researches, vol. xi, 1914, page 307.
† Proc. Roy. Soc. A., vol. xci, 1914.

* See ENGINEERING, September 8, 1922, page 285.
† ENGINEERING, April 8 and 15, 1908. See also Barnes' "Hydraulic Flow Reviewed," page 104.

GAS PLANT WITH DEMPSTER-TOOGOOD RETORTS AT SWINDON.

CONSTRUCTED BY MESSRS. R. DEMPSTER AND SONS, LIMITED, ENGINEERS, ELLAND, YORKSHIRE.

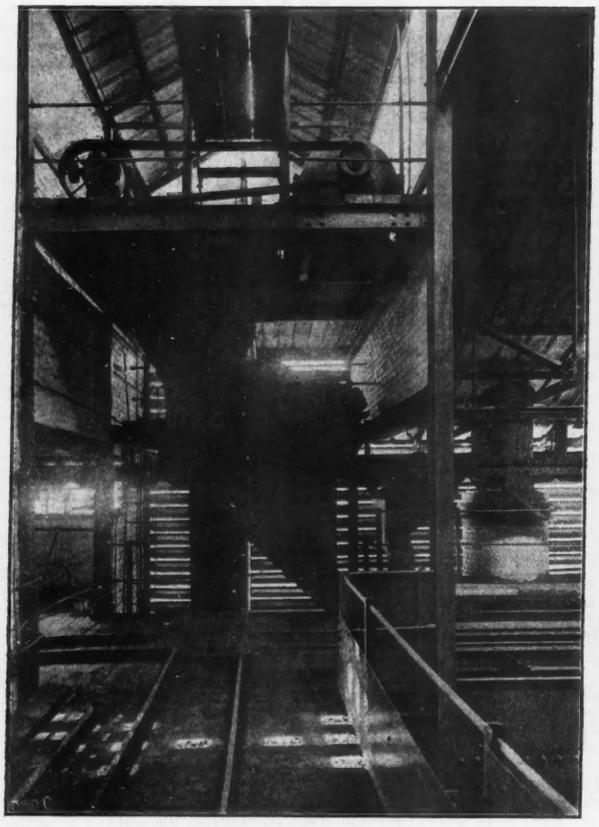


FIG. 53. UPPER END OF COAL ELEVATOR IN RETORT HOUSE.

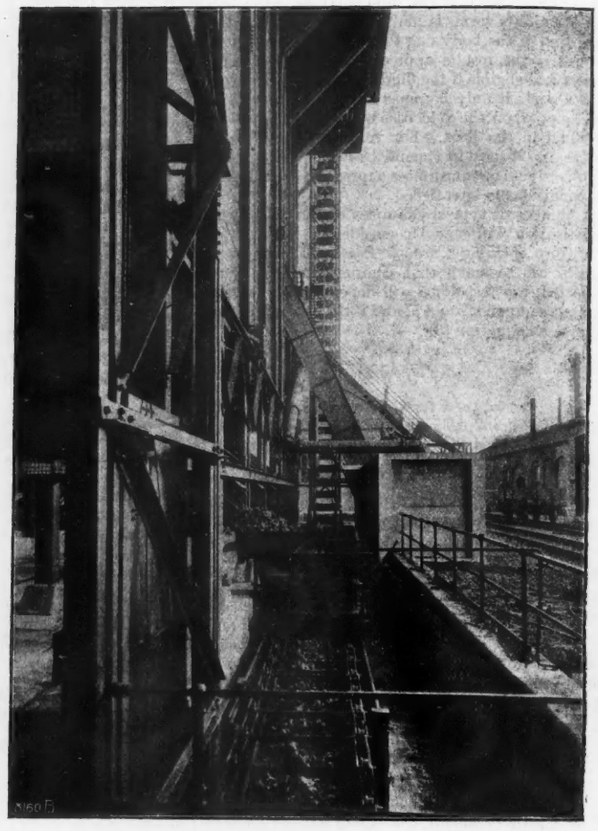


FIG. 54. GRAVITY BUCKET CONVEYOR SHOWING MOVABLE FILLER.

COAL-GAS PLANT AT THE GREAT WESTERN RAILWAY WORKS, SWINDON.

(*Continued from page* 229.)

IT will be obvious that in the design of any installation of continuous-vertical retorts, great care must be taken that the supply of coal to the retorts and the removal of the coke formed in them shall be able to proceed without interruption, even in the event of a breakdown in the normal arrangements for handling these materials. At Swindon, special attention has been given to this point in designing the coal and coke-handling plant, which we now propose to describe, and as evidence of this we may mention that coal can be supplied to the retort bunkers, referred to in our previous article, on page 228 *ante*, by four different means.

The general arrangement of the coal-handling plant is best shown in Figs. 5, 6 and 7, on Plate IX, published with our issue of February 8 last. The coal is generally delivered to the works in hopper-bottom wagons, each holding an average of 12 tons, and running on standard-gauge tracks laid on both sides of the plant. At the inner end of the retort-house building, the track runs over a concrete pit covered by a large-mesh screen which acts as a guard for the workmen, and also excludes large objects such as planks, &c. Through this screen the coal is dumped from the bottoms of the wagons into a steel-plate hopper shown in Figs. 5 and 6. The arrangement of the pit is illustrated in greater detail in Figs. 55, 56 and 57 on Plate XXV, published with this issue, these figures giving a transverse section, a longitudinal section and a plan, respectively. By means of an adjustable reciprocating tray, best shown in Fig. 56, the coal is fed into a four-roll breaking machine, which reduces it to 2 in. or 3 in. lumps, and from this machine the broken coal falls through a chute directly into the boot of a bucket elevator. As will be understood from the illustrations, the crushing machine is driven by a 20 h.p. motor situated on the ground level, while the reciprocating tray which feeds the coal into the machine is operated by chain drive and bevel gearing from the lower sprockets of the elevator; the latter is driven by a 20 h.p. motor from the upper end. This arrangement, it will be understood, ensures the transfer of the coal at a uniform rate, regardless of its size, and since the tray feeding coal to the breaker is driven from the elevator, it follows that if the latter should stop from any cause, the supply of coal to the breaker is automatically cut off so that there is no possibility of choking the machine.

As shown in Fig. 6, previously referred to, the coal-handling arrangements are exactly duplicated on each side of the retort house and the two plants are together capable of handling 100 tons per hour. Under normal working conditions, the coal is delivered from the outlet at the upper end of the elevator through a fixed rotary filler on to a gravity-bucket conveyor which carries it along over the bunkers. There are two of these conveyors completely encircling the retort-house and coke-plant buildings, one on each side, and they are also used for coke handling as will be explained later. By means of the usual bucket-tipping device, the coal can be delivered from the conveyor into any of the coal compartments of the bunkers, but in connection with this operation it should be pointed out that as the centre line of the conveyor is not exactly over that of the bunkers, steel-plate funnels are provided over each coal compartment to ensure central delivery. This is desirable since, otherwise, the proportions of nuts and fine coal delivered on each side of the centre line would be different, and consequently, as will be understood on reference to Fig. 6, one line of retorts would receive an undue proportion of fine coal and *vice versa*.

The method of coal-handling so far described is, of course, dependent upon the operation of the gravity-bucket conveyors, but if these should be out of action for any reason, the coal can be delivered from the elevator outlets into side-dumping wagons and conveyed in these to the bunker compartments. The arrangements for this purpose will be understood on reference to Fig. 6 on Plate IX *ante*, from which it will be seen that a flap valve provided in the elevator outlet enables the coal to be delivered either through the rotary filler, previously mentioned, on to the conveyor or through a hopper having a valve-controlled outlet into one of the dumping wagons. Fig. 53, annexed, is a photographic illustration of the upper end of one of the elevators showing the driving gear, the rotary filler, and the hopper for filling the wagons. The filled wagons are pushed by hand along a 2 ft. gauge track and their contents dumped through side doors into the bunker compartments. The tracks which run along over the bunkers on each side of the retort house are connected by transverse tracks with turntables at each end, so that wagons filled on one side of the retort house can be discharged on the other side, and thus if either elevator is in operation all the coal can be handled in this way; the tracks and one of the turntables are clearly shown in Fig. 53.

The design and construction of one of the dumping wagons, which hold 27 cwt. of coal or 17 cwt. of coke, are illustrated in Figs. 58 and 59, Plate XXV. The body, it will be seen, is constructed from ½-in. steel plate connected at the corners by 2 in. by 2 in. by ¼ in. angles, and is divided into two compartments by a central division plate. The

bottom slopes downwards on each side from a central ridge, and inclined hinged doors extend along the whole length of each side of the body, as shown in Fig. 58. Through these doors, which are operated by hand levers, half the contents of the wagon can be dumped on either side. The body is supported on an angle-iron frame which rests on sole bars consisting of 5 in. by 3 in. channels. The 4-in. by 4-in. by ⅜-in. tee-bar riveted to the bottom flanges midway between the wheels, as shown in Fig. 59, is provided to engage with automatic catches on the platform of the hoist when the wagons are raised or lowered by that means, as will be described later. The wheels are of cast steel and they run on ball bearings mounted on the turned ends of square axles bolted to the sole bars. The arrangement of the wheels, ball bearings and axles will be clear from an examination of Fig. 60 without further explanation, but we may mention that as a result of the use of the ball bearings the wagons, when fully loaded, can be propelled quite easily by one man. Altogether four of these wagons are in use at Swindon for handling both coal and coke in emergencies. As previously stated, the wagons can be filled with coal from either of the elevators at the bunker-top level if the conveyor should be out of action, but if both elevators should also be rendered inoperative, coal can be loaded into the wagons by hand on the ground level, the wagons being raised to the bunker-top level by means of the electric hoist mentioned in our first article on page 166 *ante*. Two of these hoists, the framework for which is shown near the centre of Fig. 5 on Plate IX *ante*, are provided between the retort house and the coke plant. The hoists are capable of raising a load of 2 tons at a speed of 100 ft. per minute and of delivering it on to any of the working levels of either the retort house or the coke plant. The platforms of the hoists are provided with rails forming a continuation of the narrow-gauge tracks, both at the ground level and at the bunker-top level, so that the dumping wagons can be run on to them and raised or lowered as required. The other emergency means of supplying coal to the bunkers, which brings the methods available up to four, as previously mentioned, is to shovel it by hand into the conveyors at the ground level, the conveyors carrying it right round the coke plant and back again over the retort-house bunkers, into which it is delivered by the ordinary tipping appliances.

In normal circumstances, that part of the coke required for use in the producers, amounting to about 14 per cent. by weight of the coal carbonised, is carried round by the gravity-bucket conveyors into which it is delivered straight from the retorts, as previously explained, and tipped directly into the overhead bunkers. The coke can, however, be handled independently of the conveyors and supplied both to the retort-house bunkers or to those of the screening plant by means of the dumping wagons. The narrow-gauge track upon which the wagons run is extended along under both retort benches so that the coke can be dropped into the wagons from the coke receptacles of the retorts, the filled wagons being then run along and raised by the hoists, as explained in connection with the emergency coal-handling arrangements. At the bunker-top level, the wagons can be pushed towards the left (see Figs. 5 and 7 on Plate IX *ante*) to supply the retort-house bunkers and to the right to supply the screening plant. Thus both coal and coke can be dealt with to an extent sufficient to keep the plant in full operation quite independently of the working of the conveyors and elevators which provide the normal means for handling these materials. It should, perhaps, be mentioned here, that the loaded wagons always travel in the same direction—either towards the hoist at the ground level or away from it at the upper level. It has thus been possible, by laying the tracks with a slight inclination, to make use of the force of gravity to reduce the manual effort required to propel the wagons.

The general arrangement of the gravity-bucket conveyors, to which frequent reference has already been made, can best be followed by an inspection of the longitudinal section, transverse section and plan of the complete plant reproduced in Figs. 5, 6 and 7, on Plate IX *ante*. As already stated, the two conveyors encircle both the retort-house and coke-plant buildings on each side. The conveyors run along in shallow troughs in the floor of the retort house below the benches, and are continued along in the open close to the side of the coke-plant building, rising vertically at the ends as shown in Fig. 54, on page 328 and also in Fig. 1 on page 165 *ante*. The vertical strands are enclosed in steel-lattice frames which support the guides and, at the top of the coke-plant building, the conveyors run horizontally in projecting passages supported on raking struts and continued along to the end of the retort house. In the latter, the conveyors run along over the bunkers, as previously mentioned, and descend vertically inside the building at the far end to connect with the lower horizontal strands. The length of the horizontal strands, in each case, is 210 ft., measured between the centres of the sprockets, while the height of the vertical strands is 70 ft., giving a total length of 560 ft. for each of the conveyors. The buckets, of which there are 280 in each conveyor, are of pressed sheet steel measuring 29 in. long, 21½ in. wide and 13½ in. deep, and they are pivoted at each end to the links of a chain fitted with flanged wheels at the joint between each pair of links. The wheels run on steel angle bars which support the load in the horizontal strands and between guides, to prevent swinging, in the vertical strands. For taking up the slack in the conveyor chains the idler drums at the ground level are carried in frames and are adjustable by means of screw gear. Each conveyor runs at 48 ft. per minute, at which speed it is capable of handling 25 tons of coke per hour.

The driving gear for the conveyors is located in the upper horizontal strands at the outer end of the coke-plant building, as indicated in Fig. 5 on Plate IX *ante*, the arrangements being illustrated in greater detail in Figs. 61 to 70 on Plate XXV of this issue. From Figs. 62, 63 and 64 it will be seen that a 20 h.p. motor running at 620 r.p.m. drives, through a 6 in. balata belt, a shaft running at 191 r.p.m. A pinion on the end of this shaft drives a second shaft at 24 r.p.m., while a spurwheel keyed on to the centre of the second shaft engages with a similar wheel on a third shaft. A pinion on the end of the latter drives a shaft carrying two hexagonal driving wheels, on which the links of the conveyor chains fit as indicated diagrammatically in Fig. 65. This shaft runs at an average speed of 4 r.p.m., but its speed of rotation is accelerated and retarded six times per revolution to compensate for the difference between the radii of the angles and flats of the hexagons. This is accomplished by the two spur wheels connecting the second and third shafts, above referred to, the two wheels, which have the same number of teeth, being eccentrically mounted as indicated in Fig. 66. The arrangement is clearly illustrated in Figs. 67 to 70, Figs. 67 and 68 being drawn with one of the flats of the hexagon uppermost, and Figs. 69 and 70 with one of the angles uppermost. It will be obvious that if the hexagons rotated uniformly, the conveyor chain would travel faster when driven from the angles than when driven from the flats, and the constant acceleration and retardation of the heavily-loaded conveyor would absorb a considerable amount of energy and would also involve a very uneven driving torque. The compensating gears, however, speed up the driving shaft when the flats of the hexagons are uppermost and slow it down when the angles are uppermost, the degree of eccentricity of the gears being calculated so as to render the linear speed of the conveyor chains practically constant. It should, perhaps, be mentioned in passing, that Figs. 67 to 70 are included only to illustrate the principle of the compensating drive. They do not represent the actual arrangement of the gear at Swindon where the strands approach and leave the hexagonal driving wheels at right angles, as indicated in Fig. 65, and not parallel to each other, as drawn in Figs. 67 and 69. Fig. 61 shows a chute down which coke is tipped from the conveyor buckets into one of the bunkers of the coke plant, which will be dealt with later.

When describing the mechanism for extracting the coke from the retorts, on page 229 *ante*, we referred to the use of a movable rotary filler for loading it on to the gravity-bucket conveyor uniformly and without spilling, and a photographic illustration showing the appearance of the filler was reproduced in Fig. 34 on Plate XV published with our issue of the 22nd ultimo. Four of these movable fillers are employed at Swindon, two on each of the lower horizontal strands of the two conveyors. One filler, in each case, is used to deal with the coke from the retorts, while the other, which can be seen in Fig. 54 on page 328, is employed to load coke on to the conveyor from the bunkers of the coke plant. The design and construction of one of the movable fillers is illustrated in Figs. 71 and 72 on Plate XXV, while in Figs. 73 to 78, on the same plate, are reproduced drawings of one of the two somewhat similar, but fixed, fillers used to deliver coal from the elevators on to the upper strands of the conveyors, as explained above. The movable filler, as will be clear from Figs. 71 and 72, is mounted on a platform constructed of steel plates and sections and supported on four ball-bearing wheels which run on rails laid on each side of the conveyor. The wheels on the right of Fig. 72, have double flanges while those on the left are without flanges. A short shaft running in a pedestal on the right of Fig. 72 carries at its free end a cast-iron drum of which the end on the left of the figure is open. The periphery of the drum is formed with six equally-spaced rectangular openings, the arrangement of which can be followed by a careful examination of Fig. 71. The free end of the drum is supported on a pair of ball-bearing rollers located as shown in Fig. 71. The design of these rollers is illustrated in Fig. 77, which gives a longitudinal section and an end elevation of an exactly similar roller used for the fixed filler. Keyed on to the shaft supporting the drum is a sprocket wheel built up of two ½-in. steel plates of the shape illustrated in Fig. 78 and bolted on to a cast-iron centre disc, details of which are given in Fig. 76. The plates are also connected by bolts fitted with tubular distance pieces, best shown in Fig. 72. Of the two plates forming the sprocket wheel, the outer one engages with the pins of the conveyor chain, as is most clearly shown in Fig. 73, while the inner plate is placed so that the six large teeth formed on its edge pass down between the wheels of the conveyor chain close to the ends of the buckets, as shown in Figs. 72 and 73. The longitudinal motion of the conveyor chain thus drives the sprocket wheel, and consequently the drum, so that the openings in the periphery of the latter always coincide with those of the buckets and the partitions between the openings in the drum cover the gaps between the buckets.

For the operation of removing the coke from the receptables of the retorts, the filler is moved along the rails so that the hopper, shown in Figs. 71 and 72, is immediately below the doors of the receptable. The movement, it should be explained, is effected by means of the conveyor itself, the filling drum being locked by the hand-operated brake, shown in the illustrations, so that neither it, nor the sprocket-wheel, can rotate. The sprocket-wheel, of course, still engages with the conveyor chain, so that the filler is drawn along by the moving chain. When the required position is reached, the brake is released and the filler is clamped to the rails by means of the hand-lever shown on the left of Fig. 71 and on the right of Fig. 72, the lever operating the clamps by means of toggle mechanism indicated by dotted lines in the right-hand bottom corner of Fig. 72. The coke which falls into the hopper when the doors are opened, is fed into the interior of the filling drum at a uniform rate, in order to prevent choking, by means of a paddle formed with six radial blades as shown in Fig. 72. The paddle is driven from a bevel ring bolted on to the end of the drum and most clearly shown in Fig. 34 on Plate XV *ante*. The drum is, of course, rotating as described above, so that the openings always coincide with the buckets and the coke is thus delivered into the latter in uniform quantities and prevented from falling between them. There is no tendency for the coke to spill over from the ends of the buckets nearest the hopper since it is directed by the feed paddle towards the opposite ends, at which spilling is prevented by the inner plate of the sprocket wheel. To

return the filler to the end of the retort house, after the whole of the coke receptacles have been discharged, it is pushed along the rails by hand, the conveyor being stationary during this operation.

The arrangement of the fixed filler can be followed from the drawings reproduced in Figs. 73 and 74 with but little explanation, since it operates on the same principle as has been described in connection with the movable filler. It will be noticed that, in the former, the filling drum is placed so that its periphery is about a foot above the centre-line of the conveyor chain, the drum being positively driven from the sprocket wheel by a chain; no feed paddle is fitted to the filling drum in this case since the filler has only to deal with measured quantities of coal delivered by the elevator buckets. A key plan of the driving arrangements, and of the framework supporting the filler, is given in Fig. 75, and the details illustrated in Figs. 76, 77 and 78 are common to both fixed and movable fillers.

All the coke handled by the conveyors, except that used in the retort-house producers, is taken to the coke-plant building where it is either stored in bunkers as received, or broken, screened and washed according to the requirements of the works where the whole of it is utilised; none is sold to outside consumers. We shall deal with the plant for this purpose in our next article.

(To be continued.)

PROPERTIES OF GASES IN HIGH AND LOW VACUA.

FOR his course of lectures at the Royal Institution this year, Sir Ernest Rutherford, F.R.S., has chosen the subject of the "Properties of Gases in High and Low Vacua." The first lecture of the course was delivered on Saturday afternoon last, and dealt with the history of the production of vacua from the original experiments of Torricelli in 1643 up to and including the introduction of the Gæde molecular pump in 1912.

Sir Ernest Rutherford said that this history was of very great interest, since every new development in the technique of producing high vacua had been followed by important discoveries, included amongst which might be mentioned the beautiful effects produced in the passage of electricity through vacuum tubes, the discovery of the cathode rays, and the laws of fluid friction at very low pressures. To this last must be added the discovery of X-rays and of the nature of the electron, whilst the manufacture of the electric valves now so widely used was dependent on the production of the highest possible vacua.

The discovery by Torricelli in 1643 that mercury would not stand in inverted tubes at a greater height than some 30 in., led to experiments by the academicians of Florence, who assumed that the vacuum above the mercury was perfect. Very little advance was made here. Great progress was, however, made by Von Guericke in the years 1650 to 1670. This investigator invented the air pump and independently discovered the Torricellian vacuum, and further noted that the height of the barometer varied from day to day and that this variation was an indication of weather changes. In his researches Von Guericke got down to about $\frac{1}{1,000}$ of an atmosphere, and his experiments with the "Magdeburg" hemispheres was referred to in all school books. For his experiments on the spring of air, Robert Boyle modified Von Guericke's air pump and in the two succeeding centuries little more was done. During 1840 to 1850, however, the mercury pump was introduced, of which one form was due to Geisler and another to Sprengel. The history of the development of the mercury pump had been very completely set forth, Sir Ernest said, in lectures delivered before the Society of Arts in 1888 by the late Silvanus Thompson. By these mercury pumps, as modified or rearranged by different workers, it was possible to get down to pressures of, say, $\frac{1}{1,000}$ mm. of mercury or about one-millionth of an atmosphere. The Sprengel type of pump had the advantage of being easily rendered automatic and of affording an indication of the stage of the exhaustion by the click produced by the mercury drops when they collided. Mercury pumps were used by Crookes in his experiments on cathode rays and the radiometer, and a study of his papers gave the impression that what Crookes did not know about high vacua was hardly worth knowing. Mercury pumps were also used in the experiments of de la Rue and Miller on the striations which were observed in vacuum tubes when an electric discharge passed under suitable conditions. In tubes showing the effect well the pressure was generally about $\frac{1}{10,000}$ of an atmosphere.

Since 1900 the art of producing high vacua had been greatly improved. The two important developments were Dewar's discovery of the fact that charcoal cooled by liquid air, had an extraordinary power of absorbing gases, and secondly, the work of Gæde, who in the first place in 1905 introduced a continuous working rotary mercury pump, and finally in 1912 invented the molecular pump, which depended on an entirely new principle, viz., the frictional drag exerted on air by a rapidly rotating solid surface. In this molecular pump, which it should be added was only used for the final stages of exhaustion, there were no valves. In principle it consisted of a cylindrical casing with an inlet and discharge opening in the periphery. Inside was a rapidly rotating disc. The air in the clearance space between the two openings was dragged forward by the moving surface, from inlet to outlet. So long as the mean free path of the air molecules is not large compared with the width of the channel between inlet and outlet, the pressure difference maintained depended on the size of this channel and on the peripheral speed of the revolutionary disc. When, however, the pressure was $\frac{1}{100}$ mm. or less the viscosity of the air became unimportant, as at such pressures molecular collisions were few in comparison with the number of impacts made with the revolving surface. In these conditions the ratio of the pressure at outlet to the pressure at the inlet depended simply on the speed and this ratio was about $\frac{1}{100,000}$ with the standard pattern of machine. The latter ran at 10,000 r.p.m. and with it exhaustion was very rapid and complete.

THE POWER STATION OF THE BRITISH EMPIRE EXHIBITION.

THE estimated demands for electricity for the illumination of the Exhibition buildings and grounds, and for the operation of the various kinds of machinery on the stands or on service, amount to a total of about 10,000 kw. The Palaces of Engineering and Industry will absorb about 2,400 kw. for power and lighting, the Colonial and Government buildings about 1,600 kw., the Amusements Park about 1,350 kw., and the Neverstop Railway about 750 kw., the remainder being required for the lighting of the grounds, restaurants, &c., and for various miscellaneous purposes. Owing to the diversity factor of the load it was considered that machinery of a rated capacity of 7,500 kw. would be sufficient to meet the maximum demand with a sufficient margin of safety, and provision has therefore been made for this amount. There are three sources of power for the Exhibition, namely, a steam generating station equipped with turbo-alternators having an aggregate rating of 4,500 kw.; an A.C. sub-station of 2,000 kw. capacity equipped with static transformers and drawing a supply of current at 11,000 volts from the mains of the North Metropolitan Power Company; and four reciprocating sets giving together an aggregate output of 1,000 kw. of direct current. The general supply to the Exhibition is three-phase alternating current on the four-wire system with 415 volts across the phases for power, and 240 volts between each phase and the neutral wire for lighting. The direct current is on the three-wire system with 440 volts across the outers, and the four reciprocating sets mentioned feed into a common network which can also be fed by three rotary converters of 500 kw. capacity each. Two of these converters are in the sub-station, and one on the stand of an exhibitor. It will, therefore, be seen that an adequate supply of electrical power of various kinds has apparently been provided, and as will be gathered from the detailed description of the plant which we propose to give, the consulting electrical engineers, Messrs. Sparks and Partners, and the British Electrical and Allied Manufacturers Association who have organised the display, have succeeded in effecting a happy combination of the two requirements of service and exhibition of apparatus.

The power station is situated on the north side of the Palace of Engineering, of which it really forms a part, the boiler room and engine room being both open to the interior of the building, so that visitors may get the fullest possible view of the whole of the plant. The power station must be judged, not in the light of a station designed as a complete unit and intended to embody the very latest ideas in central station practice, but rather as a collection of exhibits representing the varied practice of many different makers, but nevertheless co-ordinated to serve the useful purpose of supplying power to the Exhibition. Under such circumstances it would have been pardonable had the equipment presented an ill-assorted appearance, reminiscent of a museum of machinery collected in a hurry. The fact that no such idea crosses the mind, the station looking far more workmanlike and orderly than many a plant put down with no such compulsory variety of machinery, is a tribute to the engineering skill with which the selection and lay-out have been made. The excellent opportunity which the plan affords for visitors to inspect both the engine room and the boiler room, and even to see the auxiliaries in the condenser pits and the ash-handling plant in the basement, is worthy of high commendation.

The general arrangement of the power station at Wembley is shown in Figs. 1 to 8 on the opposite page. The annex in which the machinery and equipment is housed is 50 ft. wide throughout; its length of 225 ft. is divided into three portions utilised respectively as a boiler house, engine room and sub-station. The whole of the length and the end of the substation in addition are open to the interior of the Machinery Hall of the Palace of Engineering, being only separated by an iron hand railing. All the equipment is therefore in full view of visitors, inspection being facilitated by the levels of the various sections, and by a broad raised concrete gallery running alongside the engine room, from which visitors can look down upon the running machinery. The boiler room has its firing floor at a level of 18 in. above the level of the Machinery Hall. Taking this latter level as a datum, the turbine floor is at a height of 4 ft. and the substation floor at a depth of 4 ft., while the basement of the turbine room and the boiler room are both at a depth of 8 ft. 6 in. Concrete pillars at 25 ft. centres carry a 10-ton electric travelling crane of 47 ft. 6 in. span over the turbine room and sub-station for convenience of erecting and dismantling the machinery. This crane, as well as two much larger ones in the electrical section of the exhibition, was supplied by Messrs. Babcock and Wilcox, Limited.

We shall deal fully with the machinery in the turbine room at a later stage, but in order to give a more realistic impression than can be conveyed by the general arrangement drawings we reproduce in Fig. 9 on page 332 a photograph taken during the erection of the machinery. The completed unit shown in the foreground is the 1,500 kw. 3,000 rev. turbo-alternator of the British Thomson-Houston Company with condensing plant by Messrs. Cole, Marchant and Morley. This, at the time of writing, is ready for service, and awaiting only the completion of the steam piping and boiler plant. The main Reyrolle ironclad switchboard can also be seen in a very advanced state of progress in the background. The other two units which complete the generating equipment of the power station are of the same rated capacity and speed as the set already mentioned. The set next to the substation is constructed throughout by the English Electric Company, Limited, while the central set is composed of a turbine by Messrs. James Howden and Co., Limited, exhausting into a condensing plant by Messrs. John Musgrave and Sons, Limited

POWER STATION OF THE BRITISH EMPIRE EXHIBITION; GENERAL ARRANGEMENT OF MACHINERY.

Fig. 1.

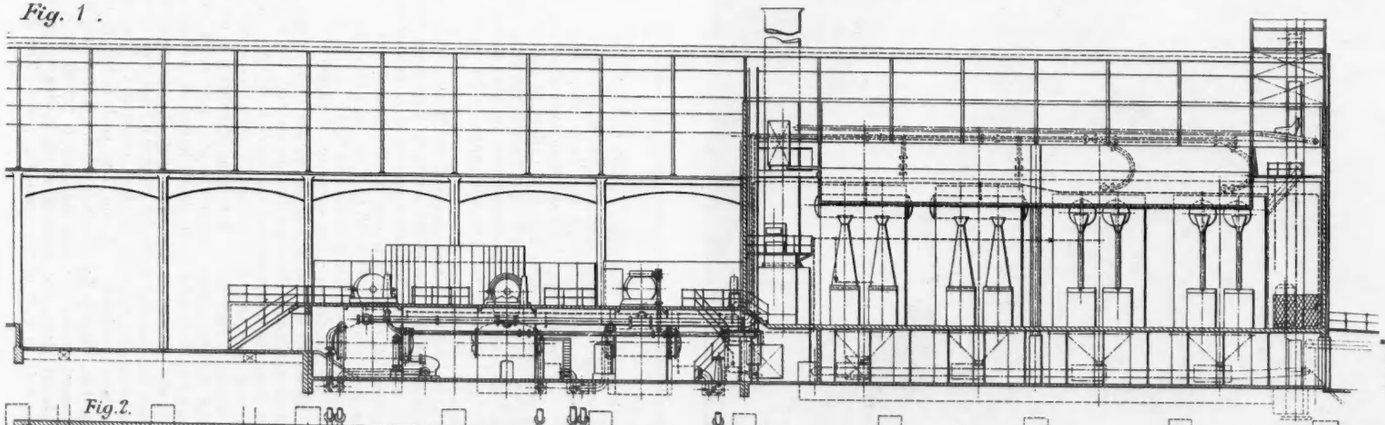


Fig. 3. JOHN THOMPSONS BOILERS

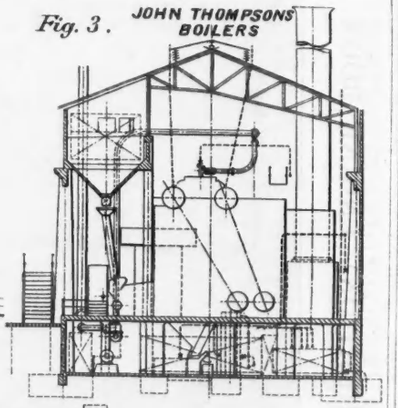


Fig. 2.

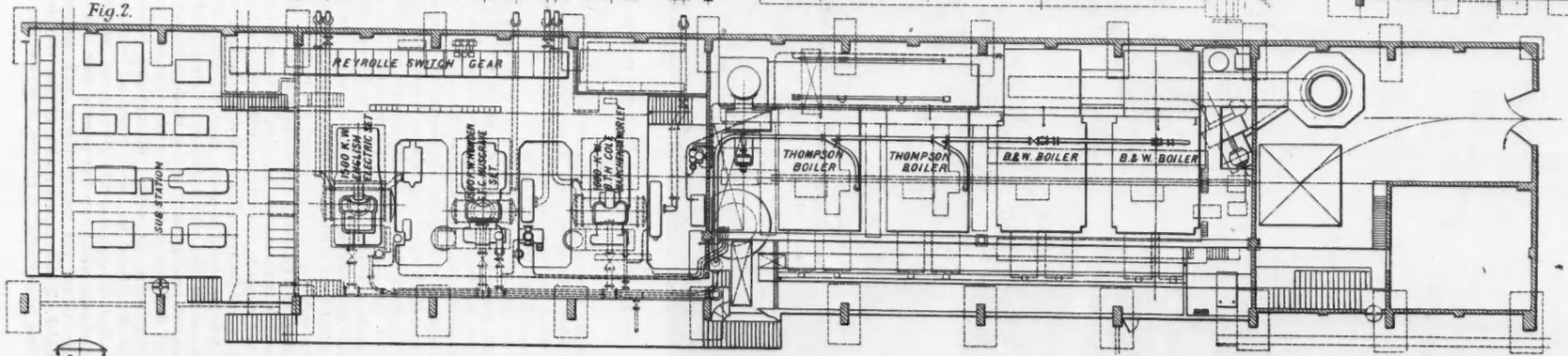


Fig. 4. BABCOCK & WILCOX BOILERS

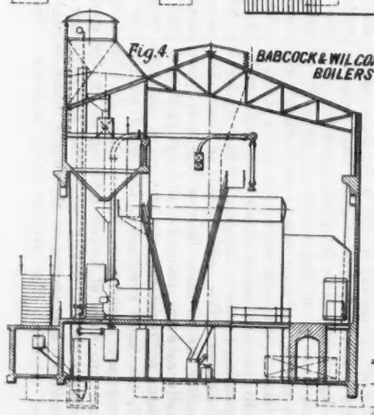


Fig. 5. SUB-STATION; ROTARIES.

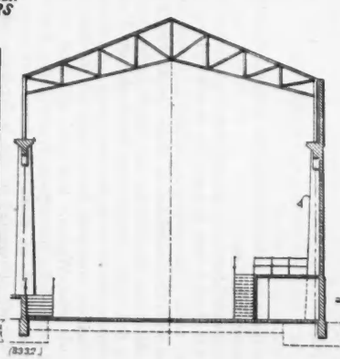


Fig. 6. ENGLISH ELECTRIC TURBO-ALTERNATOR SET.

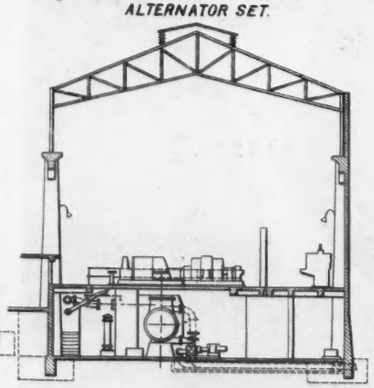


Fig. 7. HOWDEN, GENERAL ELECTRIC Co., AND MUSGRAVE.

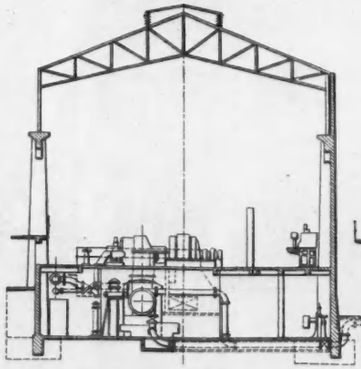
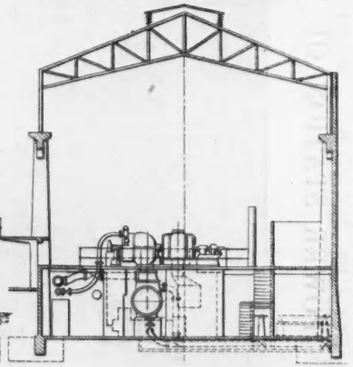


Fig. 8. BRITISH THOMSON-HOUSTON, AND COLE MARCHENT & MORLEY.



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POWER STATION OF THE BRITISH EMPIRE EXHIBITION; ENGINE ROOM.

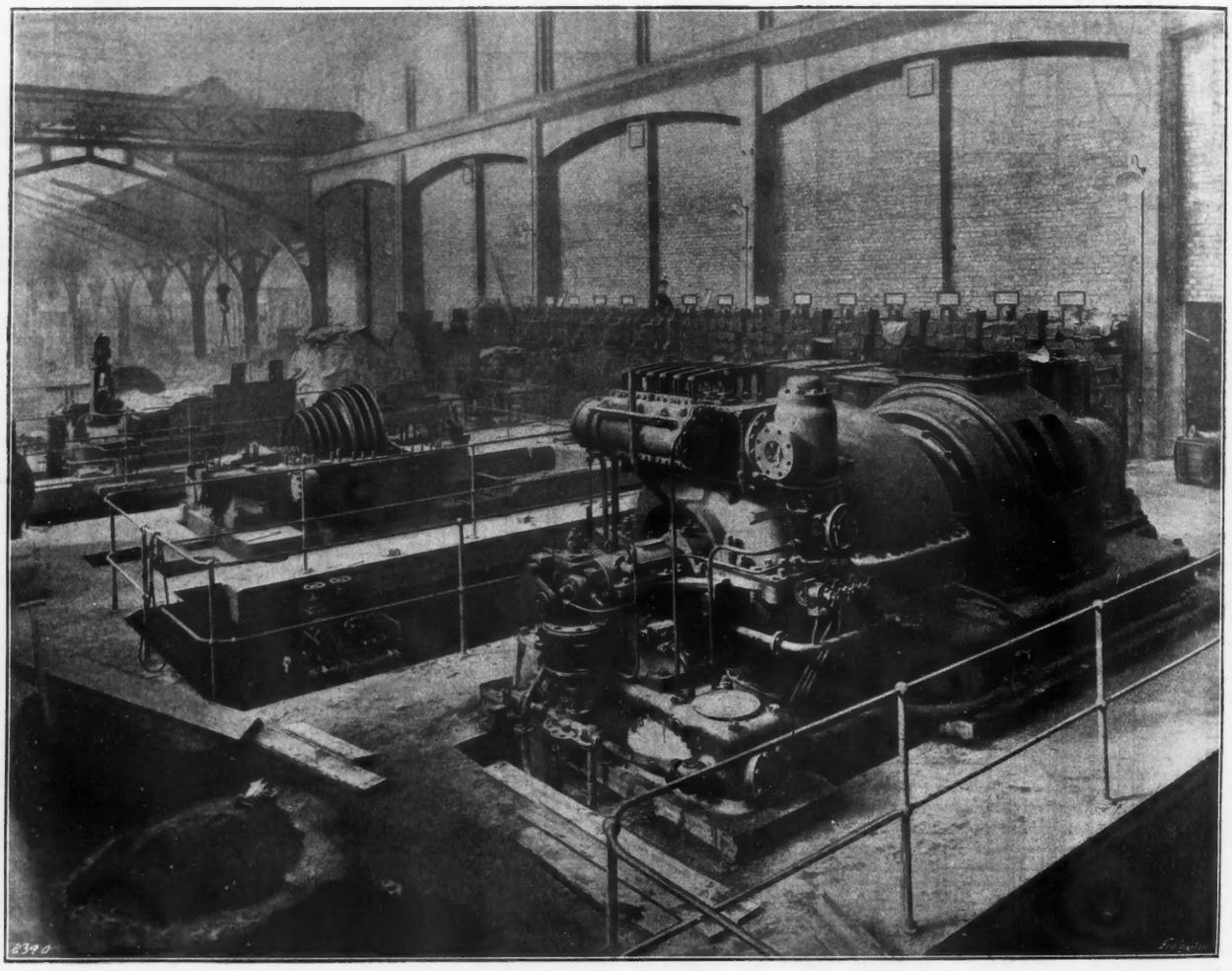


FIG. 9. VIEW TAKEN DURING THE ERECTION OF THE MACHINERY.

and driving an alternator by the General Electric Company, Limited.

The boiler house, the general lay-out of which is shown in Figs. 1 and 2, page 331, is 100 ft. long by 50 ft. wide. As already indicated the boiler fronts, with their mechanical stokers, coal weighing and measuring apparatus and other instruments are in full view of visitors to the Machinery Hall. The boiler house contains two pairs of water-tube boilers, one pair being supplied by Messrs. Babcock and Wilcox, Limited, and the other by Messrs. John Thompson Water Tube Boilers, Limited. Each of these two firms was responsible for about one-half of the boiler-house plant, and the pair of boilers supplied by each are set independently with its own economiser, flue, induced draft plant and chimney. Although all boilers receive coal from the same overhead concrete bunkers, discharge their ashes into a common ash conveyor, and supply steam to the same main, for operating purposes the plant of each maker is quite distinct. This will enable an interesting comparison to be made between the two types, especially as every boiler is fully equipped with apparatus for registering the amount of coal consumed, the water evaporated, and other matters of secondary importance. The setting, side by side, of two pairs of boilers differing so greatly in design is also interesting as showing how little the uniform appearance of the whole plant is affected thereby. The coal-conveying machinery for the whole of the boilers was supplied by The Mitchell Conveyor and Transporter Company, Limited, and the ash-conveying plant by Messrs. Babcock and Wilcox, Limited.

All the boilers supply steam at 220 lb. per square inch gauge pressure, superheated to 600 deg. F. There is, therefore, nothing spectacular about the installation, which merely represents good every-day practice of the conservative engineer. It will be regretted by many who look to Wembley to show examples of the latest developments in power plant work that the Exhibition power station does not include examples of the use of higher pressures and temperatures, the burning of coal in the pulverised form, the use of compartment-type stokers, the employment of pre-heated air, or any of the other developments which represent the most modern power station practice. We confess to a great measure of sympathy with such views, but it must be remembered that a plant of only 4,500 kw. rated capacity does not afford much scope for the representation of every kind of modern practice, and there is much to be said for the decision to make the plant primarily one suitable for the purpose of supplying power to the Exhibition, and to disregard all temptations to include apparatus which would not have been good engineering from this point of view. As it is, the visitor will see machinery and equipment which, if not representative of the very latest ideas in super-station practice, is nevertheless well abreast of anything which would be commercially justifiable in most stations of less than 5,000 kw. capacity. Within the limits they imposed upon themselves, the Exhibition authorities have done their best to include a variety of equipment, and to arrange that the products of the firms fortunate enough to be represented in the power station shall be seen to advantage under working conditions.

The boilers supplied by Messrs. Babcock and Wilcox are of the ordinary land type, each in a separate brickwork setting at a distance apart of 21 ft. centre to centre. The general arrangement is shown in Figs. 10 to 12 on page 333. Each boiler has a heating surface of 6,182 sq. ft., and has a maximum rated capacity of 25,000 lb. of steam per hour at 220 lb. per square inch. Superheaters situated between the drums and the tubes raise the temperature of the steam to 600 deg. F. There are two Babcock and Wilcox chain-grate stokers to each boiler, these being interesting as embodying the maker's latest epicyclic gear drive which we shall refer to in detail later. A further point of interest is the equipment of each stoker with a Lea coal meter for keeping an accurate check upon the quantity of fuel consumed. The counting mechanism of the Lea coal meter is operated directly by the grate itself. A small pinion which works the counting dials is driven by a toothed drum, the speed of which is directly proportional to that of the travelling grate. The position of

POWER STATION OF THE BRITISH EMPIRE EXHIBITION; BOILER PLANT.

MESSRS. BABCOCK AND WILCOX, LIMITED, ENGINEERS, LONDON.

Fig. 10.

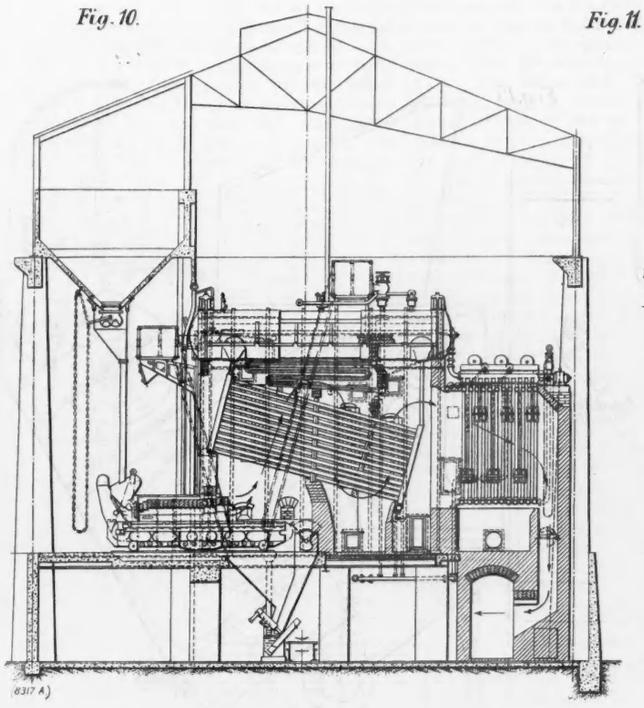


Fig. 11.

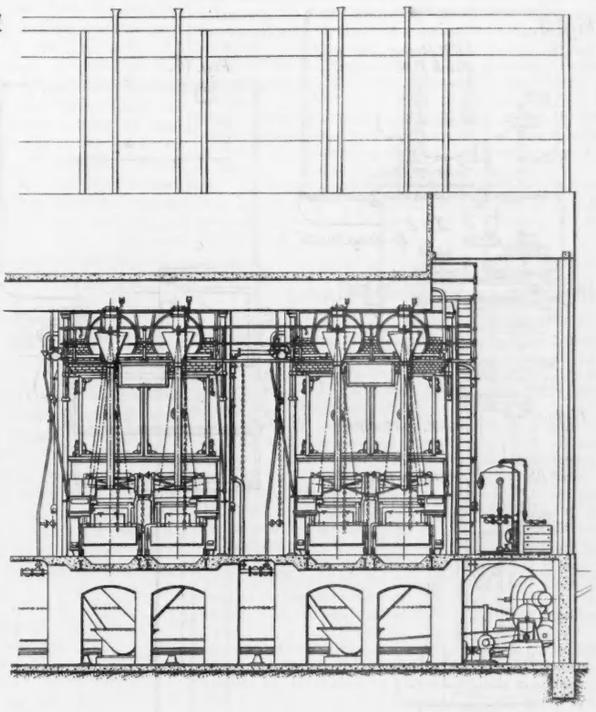
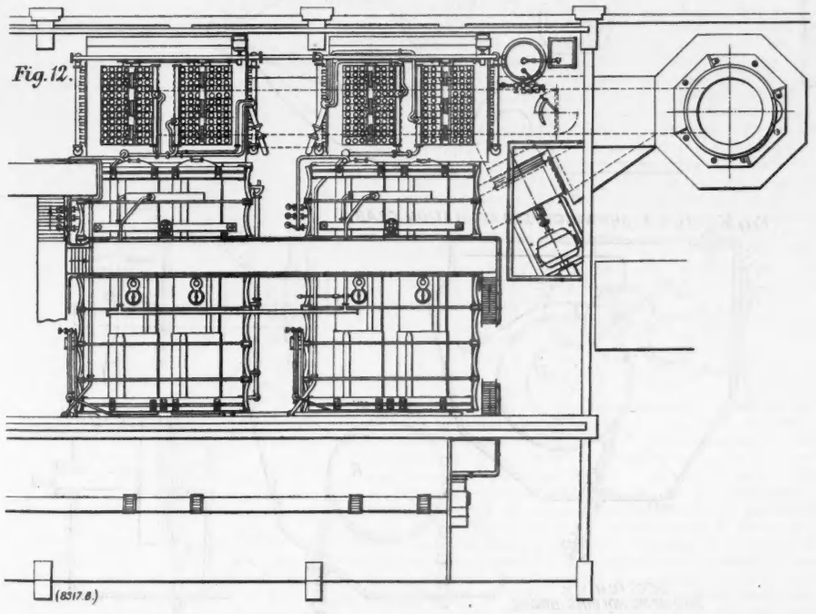


Fig. 12.



the pinion along the drum is controlled by the height of the firedoor, and is therefore proportional to the thickness of the fire. The teeth of the drum are cut away in a spiral fashion, so that the revolutions made by the pinion for each turn of the drum will vary with the position of the pinion along the drum. The dial of the counter, therefore, registers at a rate which is proportional both to the speed of the grate and to the thickness of the fire, and thus registers the quantity of coal passed into the furnace. Experience has shown that the accuracy of the Lea method of metering coal is quite sufficient for commercial work, and as the boiler house at Wembley will also be fitted with Avery coal weighers, to register the exact weight of all the coal passing from the bunkers to each stoker, engineers will have a good opportunity of comparing the performances of the two types of apparatus working in series on the same coal.

One of the Babcock and Wilcox boilers has been fitted by the makers with "Diamond" soot-blowing apparatus of the valve-in-head type, six blower elements in all being fitted and so arranged as to clean the entire heating surface of the boiler and superheater. Behind each boiler is a standard cast-iron economiser in two groups of 96 pipes each, and supplied by Messrs. E. Green and Sons, Limited, of Wakefield. The economiser is fitted with Messrs. Green's well-known scraper gear, and is, of course, designed to work at the full boiler pressure of 220 lb. per square inch. The lay-out of the economiser and flues is well shown on the drawings already referred to and in Figs. 10 and 12. There will also be seen in the corner of the boiler house the water-softening plant for the two Babcock and Wilcox boilers. This is of the Permutit type, supplied by Messrs. United Water Softeners, Limited, and works on the well-known principle of substituting for the scale-forming calcium and magnesium salts in the water the corresponding salts of sodium which remain always in solution. The active material, which has been enormously improved in efficiency since the principle was first introduced, never requires replacement. It is regenerated periodically by washing with a solution of common salt, which restores the sodium abstracted by the feed-water. No chemicals or material other than common salt are required for the operation of the softener, which will reduce water to zero hardness with no difficulty. Although the treated water is absolutely free from scale-forming salts, and therefore gives no deposit in the boilers, periodical blowing down is of course necessary in order to keep the soluble salts in the water below the limit of saturation. The Permutit plant in the Wembley Exhibition boiler house is designed to deal normally with 10,000 lb. of water per hour, reducing its hardness to zero from its original value of about 18 degrees. The installation can, however, be worked at anything up to four times the normal rating, should this be necessary.

The induced draught plant for the Babcock and Wilcox boilers is shown in Figs. 11 and 12. The flue gases, after leaving the economiser, pass downwards to a longitudinal flue directly beneath the economisers. The direct run of this flue leads straight to a self-supporting steel stack, 6 ft. diameter and 75 ft. high, just outside the boiler room. Set at an angle with the flue is a standard Sirocco fan 50-in. diameter, supplied by Messrs. Davidson and Company, Limited, of Belfast. The fan motor, like those driving the economisers and stokers, is of the British Thomson-Houston Company's manufacture. By means of a rotating damper in the main flue the gases may either be

POWER STATION OF THE BRITISH EMPIRE EXHIBITION; DETAILS OF STOKER DRIVE.

MESSRS. BABCOCK AND WILCOX, LIMITED, ENGINEERS, LONDON.

Fig. 13.

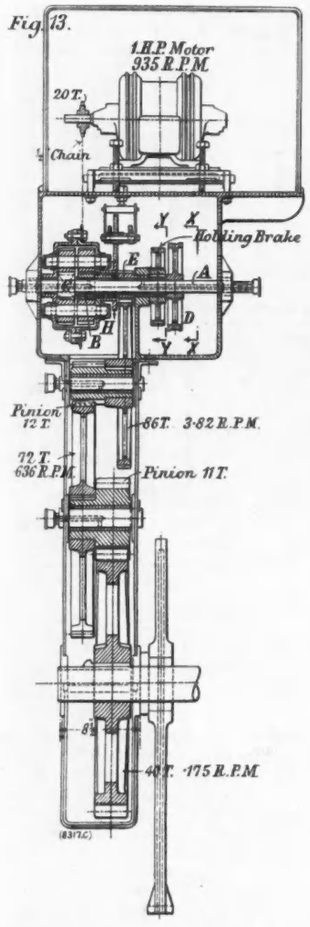


Fig. 14.

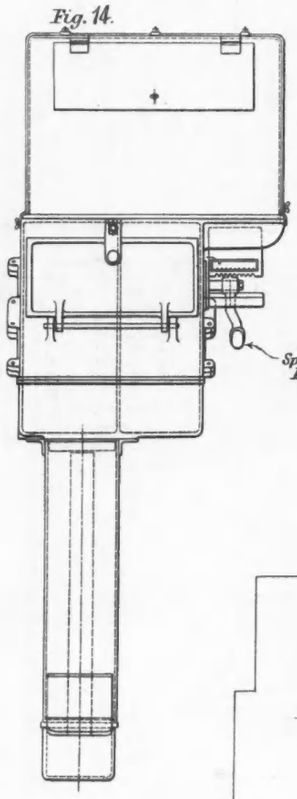
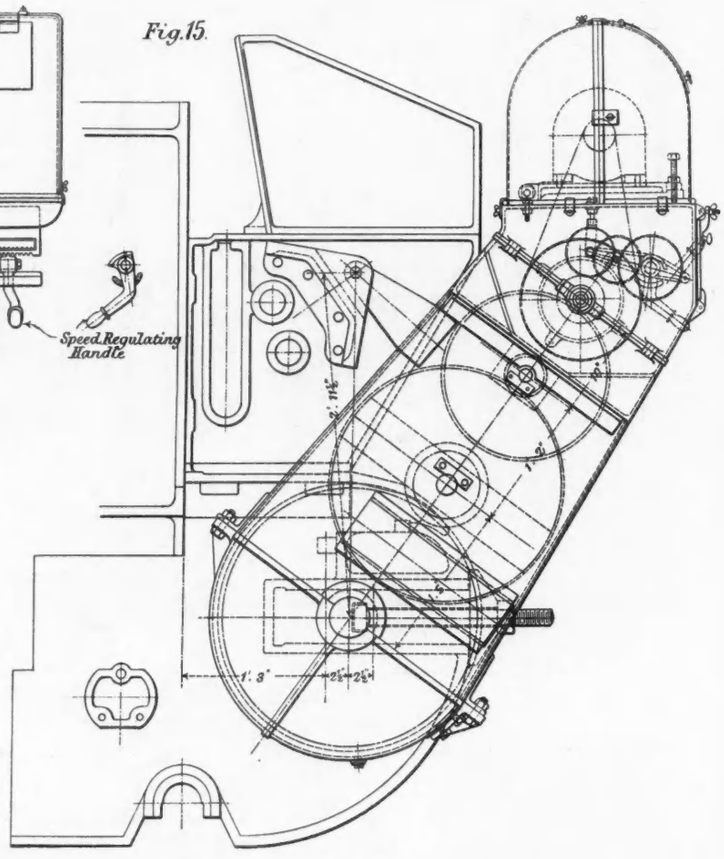


Fig. 15.



diverted through the fan, or allowed a straight path to the stack, the boilers in the latter case working with natural draught only.

The hoppers of the chain-grate stokers are supplied with coal from the overhead bunkers by means of circular shoots which are fitted with Messrs. Babcock and Wilcox's traversing device for ensuring an even distribution of the coal. With the old form of fixed shoot covering practically the full width of the hopper, it was often found that the larger lumps of the coal worked their way to the sides, the dust and very small coal being delivered at the centre. This segregation of the coal was bad for the operation of the grates as the fires did not burn uniformly, and the sides of the grates were liable to become partially uncovered and therefore to admit excess air into the furnace. With the traversing device, a parallel cylindrical shoot is used, suspended by chains from the overhead bunkers. Across the top of the hopper is a horizontal roller cut with a continuous right and left-handed screw thread. The lower end of the shoot is attached to a swivel block which engages with the screw thread, and as the roller is kept in continuous rotation by means of a drive from the stoker itself, the end of the shoot is therefore caused to keep up a continuous travel from side to side of the hopper. This ensures a perfectly uniform distribution of the fuel in the hopper independently of any variations in size, and a proper mixture of the large and small coal on all parts of the grate.

The chain grate stokers, are, as already mentioned, equipped with Messrs. Babcock and Wilcox's epicyclic gear, driving mechanism, details of which are illustrated in Figs. 13 to 19 annexed. A separate electric motor actuates each grate, so that all grates are entirely independent, and there is no shafting running along the boiler-fronts. The whole of each mechanism, including the motor, is completely housed in, so that it is protected from dust and dirt as well as from accidental derangement. Referring to Figs. 13 and 15, it will be seen that power is derived from a 1 b.h.p. motor running at 935 r.p.m. The motor spindle carries a 20-tooth sprocket wheel which drives a 78-tooth sprocket ring fixed to the circumference of the epicyclic gear case beneath. This case runs freely on the shaft A and on the sleeve of the pinion B. The planet pinions are a driving fit on their axles which run in phosphor bronze bearings in the casing. The sun-wheel C is solid with the shaft A, and keyed to the other end of the shaft is a brake drum D. It is obvious that if the shaft is held motionless and the epicyclic gear case driven round it, the pinion B will be caused to rotate, the gear being so designed that it makes one revolution for every 10·7 revolutions of the case. The pinion E is attached to pinion B by a dog-clutch and therefore revolves with it. Pinion E drives the stoker shaft by means of the train of reduction gearing shown in Figs. 13 and 15.

The motion of the stoker shaft depends upon the

Fig. 16. SEC. X X. SHOWING SPEED REGULATION GEAR.

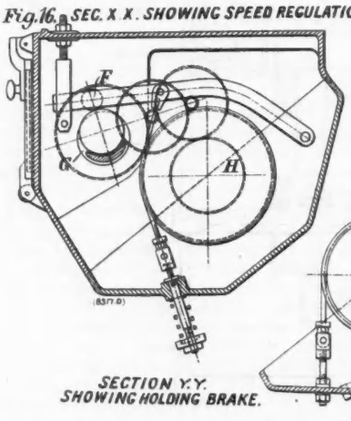


Fig. 17.

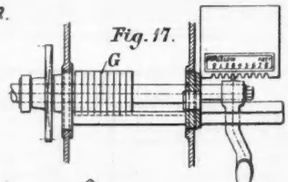


Fig. 18.

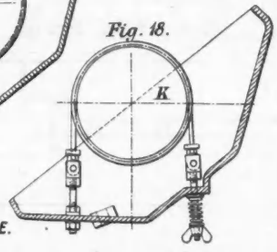
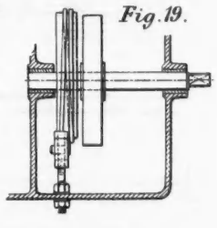


Fig. 19.



SECTION Y.Y. SHOWING HOLDING BRAKE.

brake-wheel D being held fast. If it is not held the pinion C will give less resistance to motion than pinion B and consequently the shaft will revolve while pinion B remains stationary. It is upon this fact that the speed control of the stoker depends, the pinion C being held fast by the brake-wheel for varying periods. The speed regulation gear is shown separately in Figs. 13 and 16. The brake wheel D is held by a copper band anchored at one end to the adjusting screw and attached at the other to a lever. This lever has a fulcrum at the right hand end, and near the other end it carries a roller F, which rests on a cam G. The cam is driven from a wheel H on the epicyclic

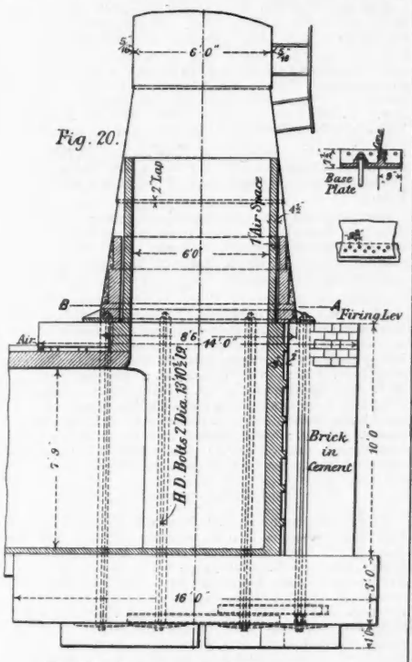


Fig. 20.

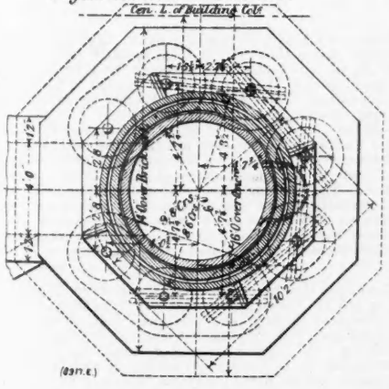


Fig. 21. SECTION ON LINE A. B.

gear casing, through the train of reduction gears shown. The cam is in one piece, but it consists virtually of a series of discs placed together. The disc at one end is complete and of large diameter. The next disc is of the same diameter, but has a part of its circumference cut away. The next one has a larger part of the rim cut away, and so on to the other end of the cam which consists of a complete disc of the smaller diameter. When the brakelever roller F rides on the large complete disc, the brake band is held taut and the gear runs constantly, this giving the fastest speed to the grate. When the roller is on the intermediate portion of the cam, the brake is released for a longer or shorter period during each revolution, and the grate thus gets a slower average speed. There are nine discs on the cam, which provides eight speeds of the grate, ranging from 2·9 ft. to 40 ft. per hour. The ninth disc has the whole of its rim cut away, and it allows of the epicyclic gear running without moving the grate at all.

The camshaft is carried in an eccentric bearing, and when the speed-controlling handle is raised the shaft and cam are swung down clear of the roller. Simultaneously the handle is freed from its locating notch, so that by pulling the handle endwise any other portion of the cam can be brought under the roller, and a corresponding speed provided for the grate. The brake wheel K is attached to the pinion E, and is fitted with a brake-band as shown in Figs. 18 and 19. The function of this brake is to prevent the tendency of the grate to run back between the driving impulses. When the grate is moving the lower part is in tension and therefore taut. When the driving impulse ceases, the weight of this part causes it to sag and thus to make the grate run back slightly. The brake acts somewhat in the nature of a ratchet and prevents this backlash. The grate can be adjusted for tension without affecting the driving gear which is completely boxed in, but is easily accessible. The epicyclic gearing consists of mild steel wheels case-hardened and ground, and the whole design is neat and efficient.

Details of the base of the 75 ft. self supporting steel chimney supplied by Messrs. Babcock and Wilcox to serve their two boilers are given in Figs. 20 and 21 on this page. The flue which is 7 ft. 9 in. high by 4 ft. wide terminates in a circular chamber to the top of which the chimney base is held by long 2 inch bolts as shown. The lower part of the steel stack is flared out in order both to broaden the base and to afford room for a short lining of 4½ in. brickwork behind which an air space is allowed.

(To be continued.)

THE LATE MR. LEONARD PESKETT.

THE Cunard Steamship Company has lost a valued servant and the naval architects, marine engineers and shipbuilders of our country a good-hearted and loyal friend, by the death, at the age of 64 years, of Mr. Leonard Peskett. He suffered a collapse through an internal trouble some four years ago and had to undergo a serious operation. Possessed of a fine physique, he soon recovered from his trial and was early back to his usual activity. Though apparently as fit as ever, this trouble may have left some effects. A man of energy frequently takes little note of the necessity for a long building-up after a serious illness, and it was thought by some of Mr. Peskett's friends that he went back to his duties after, perhaps, too short a period of rest. Whether that was so or not it seems to have been the case that some weakness remained. How unexpected his collapse was, after a short period off duty, may be judged from the fact that on Thursday last, the day prior to his death, he appeared quite bright and cheerful to those of his family and friends who were allowed to visit him.

Mr. Peskett served his apprenticeship in Rye, Sussex, and spent the following four years, from 1880 to 1884, as a draughtsman at H.M. Dockyard at Chatham. Here he earned an enviable reputation for his ability in rapidly producing solutions of difficulties encountered in the internal arrangement of vessels, and his abilities becoming known, he was appointed draughtsman to the General Superintendent of the Cunard Line, the late Captain Watson. In his new sphere of activities, first as a junior, then as ship designer, and finally as naval architect, he took part in all the great developments of shipbuilding for passenger traffic. The story of his achievements is the recent history of the Cunard Line. Changes in construction being advocated, he early appreciated their significance and with a great capacity for judging men and their purposes he could readily gauge where trust was warranted. The single-screw vessels Etruria and Umbria were being built when he entered the service of the Cunard Company. They were the last single-screwed ships the Cunard Line ever built. The next important constructions were the twin-screw sister ships Campania and Lucania. These vessels of 12,900 tons and having a speed of 22 knots for long remained the fastest on the Atlantic service. Later the company favoured a return to lower speeds and the combination of extensive provision for passengers and cargo capacity, and the Saxonia, Ivernia and Carpathia, of this type, were built between 1900 and 1902. An increase both in size and speed to 19,500 tons and 18½ knots was seen in 1905, when the Caronia and Carmania were added to the fleet. These vessels were similar, except that the Caronia was propelled by reciprocating engines through twin screws, while the Carmania had Parsons turbines operating three screws. Experiences with these two vessels gave Mr. Peskett very valuable information and data from which to judge the significance of turbine propulsion, and this proved useful in dealing with the proposals for the Lusitania and Mauretania. The latter vessels maintained a service across the Atlantic at 25 to 26 knots, and wrested the records from the Germans. As the man responsible to the company for these developments, the construction of the Aquitania and the building of the company's extensive post-war programme, Mr. Peskett must be considered as one of the greatest forces working for progress in ship design during the last quarter-century. Mr. Peskett made contributions to the Proceedings of the Institution of Naval Architects, of which he became a member in 1905, and was elected a member of council a year ago. He leaves a memory of a kindly nature which put everybody whom he appreciated immediately at their ease, and he inspired any company he entered with the true spirit of friendship.

THE LATE MR. JAMES WADDELL.

A CONSTRUCTIONAL engineer of exceptional experience, and one whose loss will be deeply felt, passed away, when Mr. James Waddell died at his home, Moray-place, Strathbungo, Glasgow, on Thursday, March 6, in his 73rd year. All who knew him were keenly appreciative of his worth and ability.

Mr. Waddell was educated at the High School of Glasgow and received his scientific training in the University of Glasgow. The succeeding four years, from 1871 to 1875, were spent in pupilage to Mr. James Deas, the Chief Engineer of the Clyde Navigation Trust. This period was one of great activity in development on the river and all the work in surveying, preparation of parliamentary papers and plans, and the start of the actual construction on the Queen's Dock was then undertaken. In this work Mr. Waddell obtained a most extensive experience. When his pupilage was over he was retained as resident engineer on the fourth contract at the Queen's Dock and acted in a similar capacity on behalf of his chief, in the erection of the large coaling cranes at the Glasgow terminus quay. Later he carried out the engineering work on many large contracts for the Morrison and Mason Company, Limited, of Glasgow. In 1878 he erected the Carlisle Citadel Station for which Messrs. Blyth and Westland, of Edinburgh, were the consulting engineers. From that work he went back to Glasgow to undertake railway construction under contracts with the Glasgow and South Western Railway. The years from 1882 to 1887 he spent in the construction of the Mugdock tunnel contract and other work in connection with the Loch Katrine water works for the supply of the city of Glasgow. From this undertaking he proceeded south to carry out similar contracts in engineering work for the city of Manchester scheme to obtain water from Thirlmere. He then erected the Rutherglen bridge over the river Clyde and the aqueduct from the source of the river Nidd to Bradford. He later reconstructed Telford's well-known bridge at Glasgow, known as the Jamaica Bridge, built the tidal weir across the Clyde and undertook much important work for the Glasgow sewage scheme. In conjunction with Sir William Arrol and Company, he built the Clyde railway bridge for the Caledonian Railway. He was elected a member of the Institution of Civil Engineers in 1906. With all his wealth of experience, he remained a modest but untiring worker. Throughout Mr. Waddell's career his successful work marked him as a painstaking and thorough engineer, while he won for himself the affection of all who were in any way associated with him.

THE LATE MR. H. M. ROUNTHWAITE.

WE regret to announce the death, which occurred on Saturday last, the 8th instant, of Mr. Henry Morrison Rounthwaite, who for nearly twenty years acted as mechanical engineer to the London County Council—first under Sir Maurice Fitzmaurice and afterwards under Mr. G. W. Humphreys, the present chief engineer to the Council. Although Mr. Rounthwaite's most important work was carried out while in the service of the Council, his name is perhaps more familiar to engineers as the joint author, with Mr. A. E. Seaton, of the well-known pocket book of marine engineering rules and tables which was first issued in 1893 and has now reached its 15th edition.

The subject of our memoir was born on December 23, 1852, so that he was in his 72nd year at the time of his death. He entered the works of the North-Eastern Marine Engineering Company at Sunderland in 1867, where he served five years as an apprentice and two years as a draughtsman. In the latter capacity he was employed by the Earles' Company at Hull, from 1874 to 1876, after which he acted for a short time as assistant and resident engineer at the Whitburn Colliery,

Durham. In 1878, Mr. Rounthwaite entered the service of Messrs. Wm. Doxford and Sons, of Sunderland, as chief draughtsman and assistant works manager, retaining this position until 1882 when he joined the staff of Messrs. Maudslay, Sons and Field at Lambeth, where he remained for about ten years. In this connection we may refer our readers to an interesting account of some of the old machine tools employed at these works, of which particulars will be found on pages 65 and 134 of our 71st volume.

After leaving the Lambeth works in 1892, Mr. Rounthwaite set up as a consulting engineer, with offices in Victoria Street, Westminster, and in this business he was engaged until 1903, when he was appointed assistant in the Mechanical Section of the London County Council, being promoted to the position of mechanical engineer to the Council later in the same year on the death of Mr. E. T. Atkinson. Mr. Rounthwaite's first work for the Council was to design and superintend the construction of the 30 steamboats employed in the Thames service, which was started in 1905 and discontinued in the autumn of 1907. Full particulars of these vessels will be found on pages 573 and 779 of our 79th volume. His more important work, however, was in connection with the London main drainage system. Various storm-water pumping stations for the system were carried out to his designs and under his supervision, notably those at Falcon Brook, Shad Thames, and Abbey Mills. The last-mentioned pumping station, which was completed in 1912, contains seven Premier vertical gas engines, each of 400 h.p., driving 38-in. centrifugal pumps.

Prior to this, Mr. Rounthwaite installed at the Deptford sewage pumping station two six-cylinder, vertical, single-acting ram pumps, this work having been carried out in 1906-07, and later he designed the alterations necessary for compounding the four 155 h.p. beam engines at the Deptford station. Another important work carried out by the deceased gentleman from 1914 to 1915, was the extension of the Crossness sewage plant, where he installed four triple-expansion pumping engines, each of 400 h.p. and driving 38-in. Boving centrifugal pumps. Much work of a miscellaneous character, such as the design of penstocks, cast-iron culverts, flaps, &c., required for the construction and maintenance of the London sewers is carried on by the department of which Mr. Rounthwaite was head. The department, which is now under the direction of Mr. A. C. Beard, is also responsible for the upkeep of the Council's sludge steamers and of the Woolwich ferry steamers.

Mr. Rounthwaite, who was a member of both the Institution of Naval Architects and the Institution of Mechanical Engineers, was due to retire under the age limit in 1918, but his services were retained for a further period of two years on the ground that his retirement at that time would have caused inconvenience to the public services. He actually retired in June, 1920, but his services were still utilised in a consultative capacity in connection with the heating installation at the new County Hall, Lambeth, until 1922. Mr. Rounthwaite, although not greatly in the public eye in recent years, was highly esteemed by those with whom he came into immediate contact and his strongly-marked characteristics of thoroughness and integrity were particularly valuable assets to the service in which he was engaged.

AUSTRALIAN CONTRACTS FOR ENGLAND.—The Board of Trade reports that the High Commissioner for Australia in London has recently placed orders in England for the supply of approximately 214,000*l.* worth of copper and bronze wire for the Commonwealth Post and Telegraph Department. The wire, it is stated, could have been obtained some thousands of pounds cheaper on the Continent; but, following the policy, adopted now for many years, of giving preference to Empire products, the Commonwealth Government have placed the contract with British manufacturers.

RAILWAY ACCIDENT AT CREWE.—The report of Major G. L. Hall to the Ministry of Transport on the accident which occurred at Crewe, on the London, Midland and Scottish Railway, on January 9 finds the cause of this accident to have been the incorrect manipulation of levers by the signalman. This error seems to have been due solely to inadvertence and not to forgetfulness, and the man involved frankly admitted his mistake. Major Hall concludes his report with the statement that in a busy box such as that at Crewe ". . . it is to the credit of signalmen generally that they [mistakes] are relatively very infrequent. It is a commonly accepted principle that when high frequency of traffic, complexity of lay-out, inadequate view of or opportunity for observing all movements, or other special conditions exist, some automatic assistance to the signalmen is called for, such as is provided by track circuiting, whereby the actual presence of a train prevents the incorrect lowering of a signal for a following movement. This case is a typical example of the class of accident which track-circuiting has been devised to prevent, and Crewe Station is certainly a locality where its installation is desirable."

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—While in certain branches there is reflected a feeling of uneasiness arising from the unsettled state in the ranks of labour, the production of steel and engineering materials tends steadily to increase and to employ a large number of operatives. During the past week the roll of unemployed in the Sheffield district has decreased by nearly 1,000, reducing the total to 24,000 as compared with 31,000 in the corresponding week last year. Manufacture of common steel is maintained at a fairly high level, the leading plants being engaged to the extent of 70 per cent. of their capacity. Inquiries for new business, both on home and overseas account are fairly numerous, but as in the case of finished products, these continue to be at greatly cut rates, and to offer very little margin of profit. Rolling mills are still working spasmodically, having been hit by the contraction in French purchases resulting from the instability of the French and Belgian currencies. Forges and foundries are finding slightly more work to do on marine account, and British shipbuilding yards are absorbing a heavier tonnage of tools and implements. Prices in the raw and semi-finished materials section are officially unchanged, but with fuel costs generally in the ascendant there is a strong probability of early advances. Quotations are as follows: Hard basic billets, 10*l.*; soft basic billets, 9*l.*; West coast hematites, 6*l.*; East coast hematites, 5*l.* 5*s.*; Lincolnshire No. 3 foundry, 4*l.* 16*s.*; Lincolnshire forge, 4*l.* 14*s.*; Derbyshire No. 3 Foundry, 4*l.* 15*s.*; Derbyshire forge, 4*l.* 12*s.* 6*d.*; bars, 12*l.* 10*s.*; Sheets, 15*l.* Welcome activity prevails in several of the leading branches of the engineering industry. Firms supplying rolling stock and parts such as tyres, axles, and wheels are doing much better. Provincial tramway requirements are providing an increased volume of orders, many of these being in respect of renewals which have been postponed for years and are now essential in order to bring tramway services up to a reasonable level of safety and efficiency. In this connection manganese steel for points and crossings is a good medium. Electrical requirements are numerous and tend to increase with the operation of conversion schemes in this and other countries. The British mining industry is calling for increased supplies of pithead gear, coal-cutting machinery, haulage ropes and tools. Automobile builders, judging from the calls made on makers of castings and special fittings, have a good deal of work in hand. Export trade in special steels is badly hampered by currency differences. The improved conditions reported in the general tool sections are fully maintained.

South Yorkshire Coal Trade.—Owing to the continued shortage of all the principal grades of domestic and manufacturing fuel, last week's advances are upheld. Collieries have more orders on their books than they can promptly discharge. The pressure is likely to continue until there is some substantial improvement in traffic arrangement. Best steams are in strong demand, both for home use and shipment, and there is very little surplus of cobbles, nuts and slacks available for open market disposal. The Metropolitan demand for house coal continues exceptionally heavy. There is no easing in the coke position. Quotations: Best branch handpicked, 36*s.* to 39*s.*; Barnsley best Silkstone, 34*s.* to 36*s.*; Derbyshire best brights, 31*s.* to 35*s.*; Derbyshire best house coal, 27*s.* to 29*s.*; Derbyshire best large nuts, 27*s.* to 28*s.*; Derbyshire best small nuts, 20*s.* 6*d.* to 23*s.*; Yorkshire hards, 27*s.* to 30*s.*; Derbyshire hards, 25*s.* to 28*s.*; Rough slacks, 12*s.* 6*d.* to 15*s.* 6*d.*; Nutty slacks, 12*s.* to 14*s.*; Smalls, 9*s.* to 10*s.*

HYDRAULIC ENGINEERING PROBLEMS IN CONNECTION WITH NAVIGATION.—On February 25, 27 and 29 the first three of a series of six lectures under the auspices of the University of London, were delivered by Mr. O. C. A. Van Lidth de Jeude, at the Institution of Civil Engineers, Westminster. The remaining lectures will be delivered at 5 p.m. on March 17, 19 and 21, and will deal with "Harbour Engineering Abroad," "Shipping Conditions in Ports" and "The Zuiderzee Scheme." The lectures are free and are illustrated by means of lantern slides. The character of the first three lectures constitutes a strong recommendation to advanced students and others to attend the remainder in order to gain a knowledge of problems which engineers in other countries are dealing with.

PROCEEDINGS OF THE INTERNATIONAL AIR CONGRESS, 1923.—A full report of the proceedings of the International Air Congress, held in London in June last, has now been issued and is obtainable from the offices of the Royal Aeronautical Society, 7, Albemarle-street, London, W.1. The report, which has been edited for the Committee of the Congress by Lieut.-Colonel W. Lockwood Marsh, reprints the whole of the papers in full and also includes verbatim reports of all the discussions. It will be remembered that we dealt with those papers and discussions likely to be of general interest to engineers at the time of the congress, and our reports will be found on page 795 of Volume cxv and on pages 5 and 35 of Volume cxvi of ENGINEERING. The full report now issued, however, contains several papers with which we were unable to deal owing to the pressure on our space, as well as a number of written contributions to the discussions received after the termination of the congress. It thus constitutes not only a valuable record of the proceedings, but also a mine of useful information on all branches of aeronautical science. Reference to this information, we may add, will be greatly facilitated by a carefully prepared general index. The volume contains nearly 1,000 pages in cloth binding and its price is 1*l.* net.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Cleveland pig-iron sales have been on a fairly good scale lately, but have not been sufficiently large to absorb output, with the result that the already considerable stocks are still being added to, and the statistical situation is now one causing a good deal of anxiety and apprehension. Most of the business that has been put through has been for local consumption, and for despatch to Scotland, but a few of the parcels disposed of have been for export. No. 1 is 94*s.* 6*d.*; No. 3 g.m.b., 92*s.*; No. 4 foundry, 91*s.*; and No. 4 forge, 90*s.*, all f.o.t. makers works, and f.o.b. Tees. The foregoing figures are the recognised market quotations, but customers claim that they can place orders on lower terms.

Hematite.—In the East Coast hematite branch also stocks are inconveniently large. Production threatens to be rather considerably curtailed in the near future by furnaces being put out of operation. At more than one works employees are liable to 24 hours notice to terminate engagements. Thus, the present outlook cannot be described as otherwise than gloomy and discouraging. Nos. 1, 2, and 3 are on sale at 100*s.*; and No. 1 is quoted 101*s.*, but doubtless these figures could be shaded.

Foreign Ore.—Business in foreign ore is extremely quiet. A transaction in best rubio is reported at 23*s.* 6*d.* but market rates are still based on best rubio at 24*s.* c.i.f Tees.

Blastfurnace Coke.—Durham blastfurnace coke quotations are irregular. Local consumers declare they can satisfy their requirements at round about 30*s.* for good medium kinds, delivered, and state that purchases have occurred at a lower figure, but sellers quote up to 32*s.* 6*d.*

Manufactured Iron and Steel.—Sales of finished iron and steel are not easily arranged. In some branches manufacturers are busy, but many contracts are fast approaching completion. Export prices are matter of negotiation, but quotations for home business still stand: Common iron bars, 12*l.*; iron rivets, 14*l.*; packing (parallel), 9*l.*; packing (tapered), 12*l.*; steel billets (soft), 9*l.*; steel billets (medium), 10*l.*; steel billets (hard), 10*l.* 5*s.*; steel boiler plates, 13*l.* 10*s.*; steel ship, bridge, and tank plates, 10*l.* 5*s.*; steel angles, and joists, 10*l.*; heavy sections of steel rails, 9*l.*; fish plates, 13*l.*; and galvanised corrugated sheets (No. 24 gauge, in bundles), 18*l.* 15*s.*

ROADS RESEARCH.—The National Physical Laboratory has issued a revised edition of the pamphlet dealing with tests and measurements undertaken at the Roads Research Laboratory on behalf of the Ministry of Transport (Roads Department). The pamphlet gives details of the methods, regulations and fees for tests on specimens of rock to be used as road stones and for tests on materials used in the formation of dustless roads. The revised fees come into force on April 1. Copies of the pamphlet may be obtained on application to the Director, National Physical Laboratory, Teddington, Middlesex.

THE AILSA CRAIG MOTOR COMPANY, LIMITED.—This company states that reports have recently been circulated to the effect that the Secretary for War and the Commissioners of H.M. Works have applied to continue in occupation of the Ailsa Craig Works, Chiswick, for training disabled ex-soldiers. The works in question should have been referred to as the Government Instructional Factory, Chiswick, and not the Ailsa Craig works, which name applies only to the company's own factory, employed in the manufacture of Ailsa Craig marine motors. The training factory was originally built by the company during the war, and at that time was known as part of the Ailsa Craig works, but the proposals of the Government do not in any way affect the marine motor business carried on by the company.

PRODUCER GAS FURNACES.—A paper read on February 28, by Mr. Th. Teisen, before members of the Birmingham Metallurgical Society, at Wolverhampton, dealt with producer gas-fired furnaces for heating, annealing and melting metals, alloys or glass, for enamelling, &c. He pointed out that the main advantages of such furnaces, compared with the direct fired type, were economy in fuel and better control of the temperature. The furnaces could be classified, according to construction, into those having each their own producer, and those connected to a central producer; they could also be classified, according to the method of operation, into regenerative furnaces working on the system introduced by Siemens, recuperative furnaces working on the continuous system, and furnaces without heat recovery. The Siemens' system, as was well known, was applied to furnaces for working at high temperature in the making of steel and glass. The recuperative systems were also suitable for high temperatures, but stress should be laid on the point of combined safety and efficiency, also as the necessity of working with a fairly constant gas and air flow, and in this connection the horizontal plant has been found hitherto generally preferable to the vertical. With reference to the central producer plant, this had advantages in large works, and should be designed to burn ordinary local coal since a great unnecessary drawback surrounded a plant which could only run on coke. On the Continent, Mr. Teisen stated, the furnace engineer was given a greater scope than in this country, and large works were availing themselves of his services to a great extent. In regard to the oil-fired furnace, this was applicable in comparatively small plants, in larger ones a producer gas furnace was to be preferred.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—Little change of any kind has taken place in the Scottish steel trade over the week, and business all round is exceedingly slow. The long looked-for improvement is not yet, and some producers are beginning to despair of its arriving on this side of the summer holidays. The shipbuilding industry is not making much headway, but it is certainly gradually getting better, and there are prospects that the demand for ship plates will improve in the near future. Material for constructional purposes is moving with a little more freedom, and inquiries now in the market for abroad amount to quite a good tonnage. The black-sheet makers are doing fairly well at the moment, but the forward outlook is not so satisfactory, and unless bookings improve soon a quieter time at the works is sure to come along. The general inquiry for steel material is not very heavy this week, and the offer of foreign manufactured stuff at very low prices is not helping the local industry. Quotations are inclined to be easier, but show no change meantime. The following are to-day's prices:—Boiler plates, 13*l.* 10*s.* per ton; ship plates, 10*l.* 5*s.* per ton; sections, 10*l.* per ton; and sheets, $\frac{5}{16}$ to $\frac{1}{8}$ in., 12*l.* 10*s.* per ton, all delivered Glasgow stations.

Malleable Iron Trade.—The present state of the West of Scotland malleable-iron trade is not encouraging, and makers are finding no little difficulty in fixing up new business. The works are still employed mainly on old orders, and the outlook is not very bright. In the steel re-rolling branches there is a certain amount of slackness, but plant is being kept moving fairly well. Prices are unchanged with "Crown" bars called 12*l.* 10*s.* per ton delivered Glasgow stations.

Scottish Pig-Iron Trade.—The conditions in the Scottish pig-iron trade are rather unsatisfactory and, partly as the demand for iron—both foundry and hematite—has fallen so low, the furnaces in blast at Clyde Iron Works have been blown out and extensive alterations are being made. When these are completed the works will be very up to date and in a position to meet the most keen competition. Local producers are at present being faced with very cheap foundry iron from the Continent, and in many cases are losing business on that account. Home prices have gradually been brought down, and are now 5*l.* 6*s.* 3*d.* per ton for No. 1 and 5*l.* 1*s.* 3*d.* per ton for No. 3 foundry iron, both on trucks at makers' yards. In many cases consumers prefer the local grades, and stocks, which are not accumulating so rapidly owing to the smaller number of furnaces now in blast, are getting lighter. The same is the case with hematite iron, but producers are up against the foreign basic pig-iron, which seems to be suiting the steel makers fairly well. To-day's price of Scottish hematite is 5*l.* 2*s.* 6*d.* per ton, delivered at the steelworks. The demand for pig-iron overall is not very heavy and considerable stocks are held, and until a buying movement sets in little change for the better is expected in the trade. The reduction in output which has recently taken place will, of course, assist materially in bringing down stocks and will also help to keep prices from falling too low.

Shipbuilding.—Amongst orders recently secured by Clyde shipbuilders is one for a steamer of 8,000 tons for a firm of shipowners in Hull. Another order for a salvage tug of about 185 ft. in length has been booked by Messrs. Bow, McLachlan and Co., Paisley. This vessel is for Vancouver owners. Orders are also reported for two tramp steamers for the Forth one, to be built at Leith and one at Burntisland. In each case the builders will supply the machinery.

THE INSTITUTION OF RAILWAY SIGNAL ENGINEERS.—On Wednesday last a paper was read before the Institution of Railway Signal Engineers by Mr. J. Boot on "Electrical Signal Machines." This commendably brief paper described no particular machines in detail, but dealt with general points of design as affected by different conditions. The author pointed out that if an installation were compact some economy of current might be sacrificed to secure lower first cost. On the other hand, if spread out, and with automatic signalling the apparatus must be of the most efficient type to prevent high transmission losses. Signal machines could be classed as either solenoid or motor machines and these again were divided into direct-acting machines at the top of the ports, or machines operating the arm by means of down rods. Although not developed to any extent now, the author considered that there were possibilities in the solenoid machines and referred to experiments he had made with one embodying a spring interposed between the armature and the signal crank. As regards D.C. motor machines, the question of bushes was of great importance. In some of the machines the motors reversed or were liable to reverse when copper gauze or laminated bushes gave trouble. Carbon brushes were therefore more suitable both for low and high voltage machines. In connection with gearing, if spur or bevel gears were used, reversing by the arm tending to return from the "off" position had to be prevented by means of a pawl or clutch. Worm gears did not require this. The "holding off" brake had to be designed to work with a minimum of current expenditure and a satisfactory arrangement by which full current could be provided for the motor, and then a small current for the brake was difficult to secure. More care should be given to lubrication especially of machines on the posts. The bad location of oil cups, &c., often meant that bearings, &c., were not properly attended to.

NOTICES OF MEETINGS.

THE INSTITUTE OF METALS. SWANSEA LOCAL SECTION.—Saturday, March 15, at 7.15 p.m., in the Metallurgical Department, University College, Singleton Park. General discussion on the "Layout of Rolling Mills."

BRADFORD ENGINEERING SOCIETY.—Monday, March 17, at 7.30 p.m., in the hall of the Bradford Technical College. Lecture by Mr. David Flather (of Sheffield) on "The Case Hardening of Steel," illustrated by diagrams and actual samples.

THE INSTITUTION OF AUTOMOBILE ENGINEERS. GLASGOW CENTRE.—Monday, March 17, at 7.30 p.m., at the Royal Technical College, Glasgow. Paper, "Some Notes on Four-wheel Braking Systems," by Mr. F. A. S. Acres.

THE INSTITUTION OF CIVIL ENGINEERS.—Tuesday, March 18, at 6 p.m. Papers to be submitted for discussion: "The Interaction in Bridgework of the Deck System on the Main Girders, and the Consequent Modification of Stresses Therein," by Mr. Douglas Henry Remfry, B.Eng., Assoc.M.Inst.C.E. "Theory of Transverse Oscillations in Girders and its Relation to Live-Load and Impact Allowances," by Professor Charles Edward Inglis, O.B.E., M.A., M.Inst.C.E. Students' Meeting, Wednesday, March 19, at 6 p.m. Lecture on "The Work of a Mechanical Engineer's Office," by Alfred John Hill, C.B.E., M.Inst.C.E. (The delivery of this lecture had to be postponed from January 23.) Students' Visit, Wednesday (afternoon), March 26, to the locomotive shops and running-sheds of the London Midland & Scottish Railway, at Kentish Town.

THE INSTITUTE OF MARINE ENGINEERS.—Tuesday, March 18, at 6.30 p.m., at 85-88, The Minories, Tower-hill, E.1. "The Development of the Marine Steam Turbine," by Mr. G. W. Johnson.

THE INSTITUTION OF ELECTRICAL ENGINEERS: NORTH MIDLAND CENTRE.—Tuesday, March 18, at 7 p.m., at the Hotel Metropole, King-street, Leeds. Paper, "Some Researches on the Safe Use of Electricity in Coal Mines," by Professor W. M. Thornton, O.B.E., D.Sc.

THE INSTITUTE OF METALS. BIRMINGHAM LOCAL SECTION.—Tuesday, March 18, at 7 p.m., in the Chamber of Commerce, New-street. Paper on "Brittle Ranges in the Brasses," by D. Bunting, M.Sc.

THE INSTITUTE OF TRANSPORT.—Tuesday, March 18, at 5.30 p.m., in the Lecture Theatre of the Institution of Electrical Engineers, Victoria-Embankment, W.C. 2. Lecture on "Relative Efficiency of Horse and Mechanical Power for Road Transport," by Mr. E. Falconer.

SOCIETY OF GLASS TECHNOLOGY.—Wednesday, March 19, at 2.30 p.m., in St. Thomas' Hall, Stourbridge. The following papers will be read: (*a*) "The Properties of Lead-Containing Glasses," by Professor W. E. S. Turner, D.Sc. (*b*) "The Art of British Glass Decorators—The Duplication of the Portland Vase," by John Northwood.

THE ROYAL SOCIETY OF ARTS.—Wednesday, March 19, at 8 p.m., at John-street, Adelphi, W.C.2. Ordinary meeting. "The Forests and Timber Supply of North America." By R. L. Robinson. Friday, March 21, at 4.30 p.m. Indian Section. "Progress of Co-operative Banking in India," by Otto Rothfeld, I.C.S.

ROYAL METEOROLOGICAL SOCIETY.—Wednesday, March 19, at 7.30 p.m. A Lecture on "Atmospheric Electric Currents, normal and abnormal, and their relation to the growth of Plants," will be delivered by Mr. V. H. Blackman, F.R.S. (Professor of Plant Physiology, Imperial College of Science and Technology). The Chair will be taken by Mr. C. J. P. Cave, M.A., President.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, March 20, at 6 p.m. Lecture on "The Nature and Reproduction of Speech Sounds" (vowels), by Sir Richard Paget, Bart.

THE INSTITUTE OF METALS. LONDON LOCAL SECTION.—Thursday, March 20, at 8 p.m., in the rooms of the Institute of Marine Engineers, 85-88, The Minories, Tower-hill, E.1. Paper by W. B. Clarke on "Metals for Lamp Manufacture" (instead of the Open Discussion as previously announced).

THE INSTITUTION OF MINING AND METALLURGY.—Thursday, March 20, at 5.30 p.m., at the Rooms of the Geological Society, Burlington-House, Piccadilly, W. 1. Papers for discussion: "The Manufacture of Zinc and Zinc-Lead Oxide from the Complex Ores," by Mr. R. G. Hall; "The Schamva Mines, Rhodesia," by Cyril E. Parsons; "Field Methods in Sedimentary Petrography," by J. M. Flemming.

THE ILLUMINATING ENGINEERING SOCIETY.—Friday, March 21, at 8 p.m., at the Royal Society of Arts, John Street, Adelphi, W.C. 2, when discussions on "The Use of Light for Outdoor Advertisements" will be opened by Mr. G. P. Garbett, and on "The Use of Light in Shops, in Show-windows and for Display Purposes," by Miss M. Partridge, B.Sc.

THE JUNIOR INSTITUTION OF ENGINEERS. Friday, March 21, at 7.30 p.m., at 39, Victoria Street, S.W. 1. Lecturette, "Sulphuric Acid Plants, New and Old—Constructional Details and Working," by P. Parrish (Member).

THE INSTITUTION OF LOCOMOTIVE ENGINEERS (LONDON).—Friday, March 21, at 7 p.m., at the College of Technology, Sackville Street, Manchester, when a lecture, illustrated by lantern slides, will be delivered by Professor S. P. Smith, D.Sc., on "Electrification of Foreign Railways."

THE NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—Friday, March 21, at Bolbec Hall, Newcastle-on-Tyne. Paper, "The Presentation of Propeller Experiment Data," by Mr. E. F. Telfer, M.Sc.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, March 21, at 6 p.m., at Storey's-gate, Westminster, S.W.1. General meeting. Presidential address by Mr. William H. Patchell.

THE HULL ASSOCIATION OF ENGINEERS.—Saturday, March 22, at 7.15 p.m. at the Municipal Technical College, Park-street, Hull. Lecture on "Friction Linings," by Ferodo Company, Limited.

ROYAL INSTITUTION OF GREAT BRITAIN.—Afternoon lecture, Saturday, March 22, at 3 p.m. Sir Ernest Rutherford, F.R.S., on "Properties of Gases in High and Low Vacua." (Lecture III.).

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—Exports of coal as cargo from the principal South Wales ports in February amounted to 2,001,525 tons, or 289,912 tons less than in the corresponding month of last year. Shipments from Cardiff totalled 1,204,890 tons, a decrease of 232,656 tons; from Newport 414,294 tons, a decrease of 31,140 tons; from Swansea 170,472 tons, a fall of 24,173 tons; from Llanelly 28,629 tons, a reduction of 6,720 tons; and from Port Talbot to 183,240 tons, an increase of 4,777 tons. Exports to France amounted to 812,502 tons, or 29,289 tons more than in February of last year; to South America 310,730 tons, an increase of 20,417 tons; to Portugal 72,739 tons, an increase of 16,518 tons; to Greece 24,416 tons, an increase of 4,798 tons. On the other hand, shipments to Italy totalled 216,337 tons, a reduction of 116,177 tons; to Spain 143,408 tons, a decrease of 13,740 tons; to British Coaling depots to 183,026 tons, a drop of 61,155 tons; to the United State to 8,270 tons, a decrease of 121,560 tons; and to other ports were reduced by 34,881 tons. As the result of heavy chartering and a good arrival of shipping the coal market has firmed up considerably during the last few days. A week ago colliery salesmen were seeking prompt and spot orders to avoid pit stoppages because they had insufficient shipping in dock to absorb outputs. The position is now reversed, for there is an ample supply of tonnage and no fewer than 35 vessels are waiting for loading berths. There is also a good demand for coal, as both foreign and home consumers are building up stocks as a precaution against the possibility of a coal strike next month. There are a couple of Roumanian inquiries in the market, one being for 270,000 tons of coal and the other for 10,000 to 20,000 tons in five cargoes over two months. Best Admiralty large coal is firm at 31*s.* 6*d.* to 32*s.* 6*d.*, with Monmouthshires round 30*s.* and best steam smalls from 22*s.* to 23*s.*

Ship Managers' Generosity.—The managers of the Rhondda Shipping and Coal Exporting Company, Limited, Messrs. Owen and James, Cardiff, have advised the shareholders that they have not drawn any fees for the past two years, owing to the very severe depression in shipping and the law case with the charterers. On the successful termination of the law case, part of the amount due for management was drawn. As the company is not in a position to pay a dividend, owing to the excessive taxation and the heavy slump in tonnage values, the managers feel they would like to do something for the shareholders, and have decided to make an *ex.-gratia* payment entirely out of their own pockets of 1*s.* per share free of tax, involving a sum of 2,342*l.*

Iron and Steel.—Exports of iron and steel goods from South Wales last week amounted to only 2,957 tons, compared with 9,632 tons in the previous week and an average of nearly 14,000 tons per week in February and nearly 20,000 tons in January. Last week shipments consisted of 2,623 tons of tin plates and terne plates, against 3,792 tons in the previous week; 105 tons of black plates and sheets, against 4,044 tons; 201 tons of galvanised sheets, against 704 tons; and 28 tons of other iron and steel goods, against 1,092 tons.

BRITISH CLUB, COPENHAGEN.—We are informed that the British Club, 10, Vestre Boulevard, Copenhagen, B., was formally opened on the 1st inst. by H.M. Minister at Copenhagen, the Rt. Hon. Earl Granville, G.C.V.O., K.C.M.G. The club is open to British subjects visiting or passing through the town.

POCKET DIARY.—We have received from Messrs. Braithwaite and Co. (Engineers), Limited, 117, Victoria-street, S.W.1, a vest pocket diary containing a large number of useful tables regarding steel sections of British standard sizes. The little book presents a large amount of data of value to structural engineers in compact form.

FUEL RESEARCH.—The Lord President of the Council has appointed Mr. F. S. Sinnatt, M.B.E. (Mil.), M.Sc. (Tech.), F.I.C., M.I.Min.E., to be Assistant Director of Fuel Research as from April 1 next. Mr. Sinnatt is lecturer in Fuels in the University of Manchester, Faculty of Technology. He is also Director of Research to the Lancashire and Cheshire Coal Research Association, and has been in charge of the physical and chemical survey of coal seams which the association is carrying out for the Fuel Research Board in the Lancashire and Cheshire coal fields.

THE HARTEBEESTPOORT DAM; SOUTH AFRICA.

MR. A. D. LEWIS, M.INST.C.E., DIRECTOR OF IRRIGATION, ENGINEER.

(*For Description, see Page* 323.)

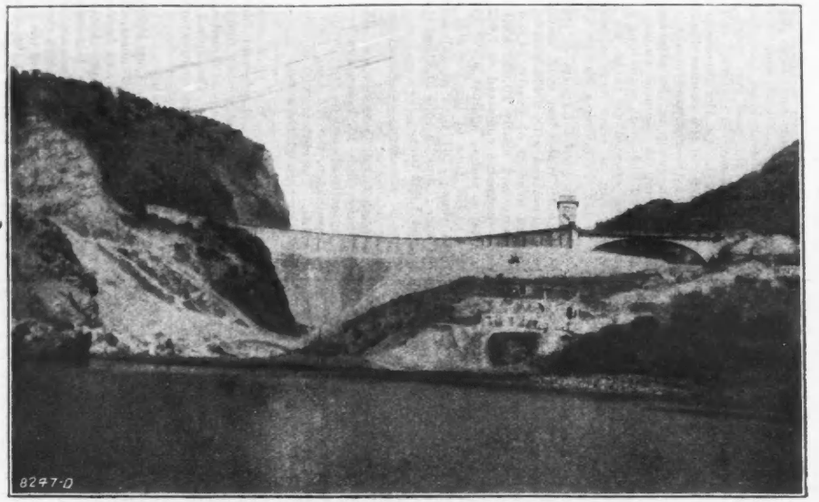


FIG. 12. VIEW OF DAM FROM DOWNSTREAM.

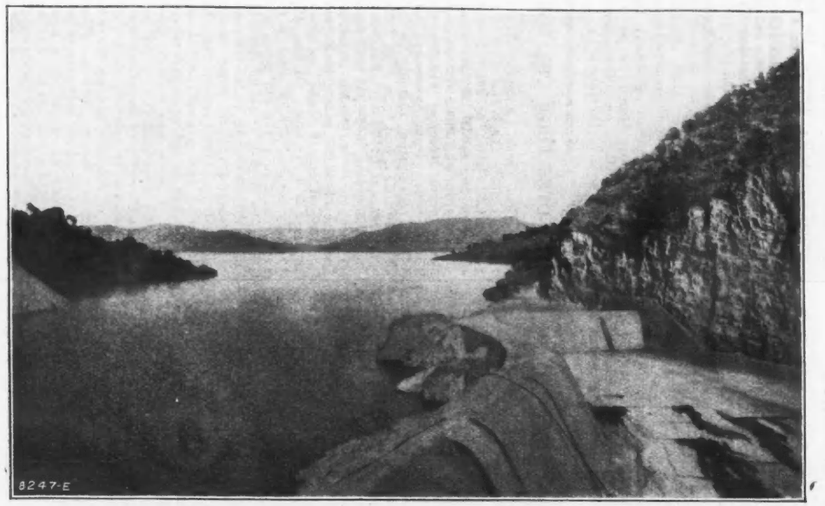


FIG. 13. THE RESERVOIR AND SPILLWAY.

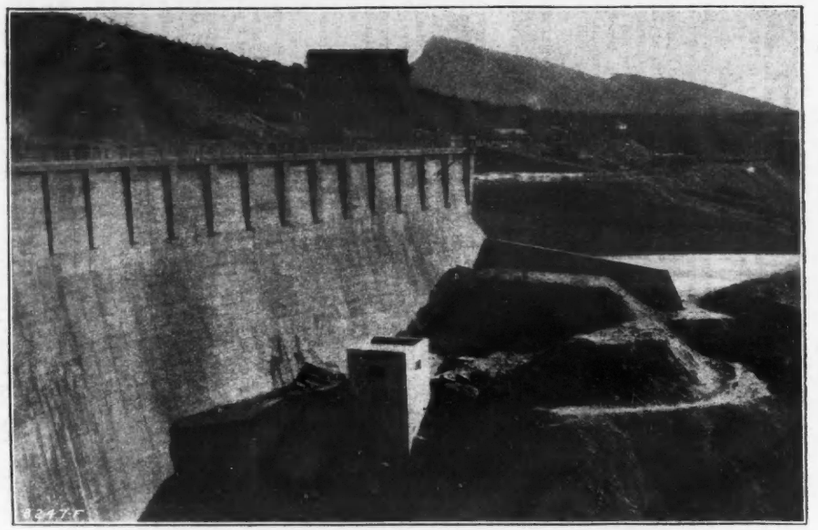


FIG. 14 WEST ABUTMENT AND SPILLWAY APRON.

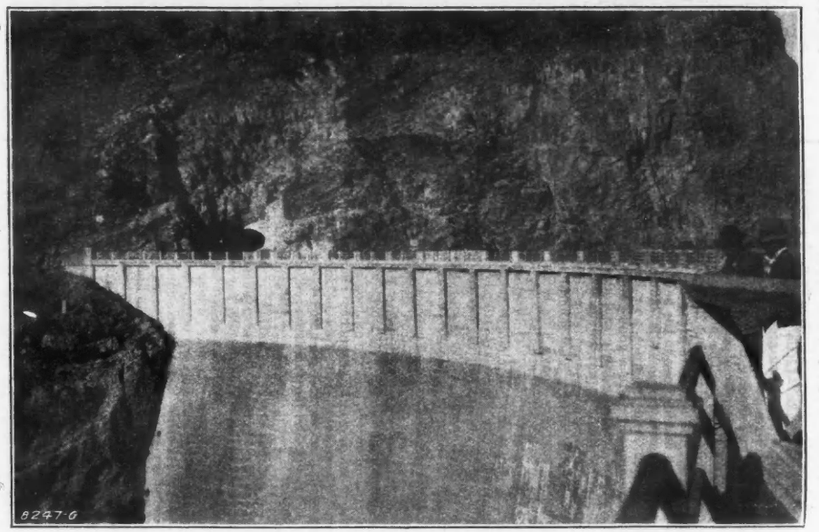


FIG. 15. EAST ABUTMENT OF DAM.

Fig. 15. East Abutment of Dam.

GAS PLANT WITH DEMPSTER-TOOGOOD CONTINUOUS VERT

CONSTRUCTED BY MESSRS. R. DEMPSTER AND SON, LIMITED

(For Description, see Page 328)

Fig. 55.

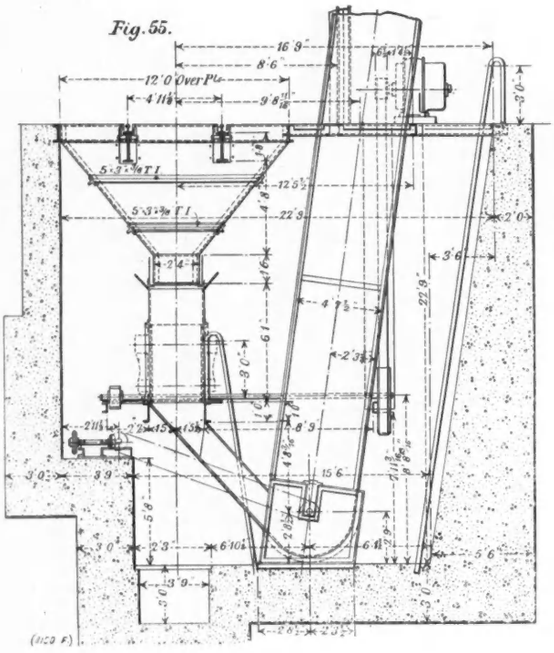


Fig. 56.

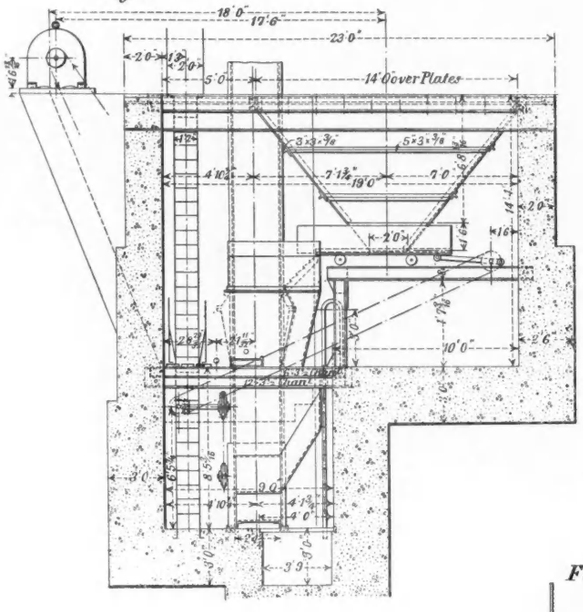


Fig. 61. ELEV. OF CHUTE IN DIRECTION OF ARROW A.

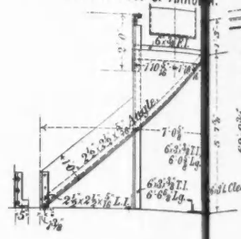


Fig. 65. DIAGRAM OF ARRANGEMENT OF DRIVE.

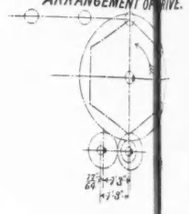


Fig. 57.

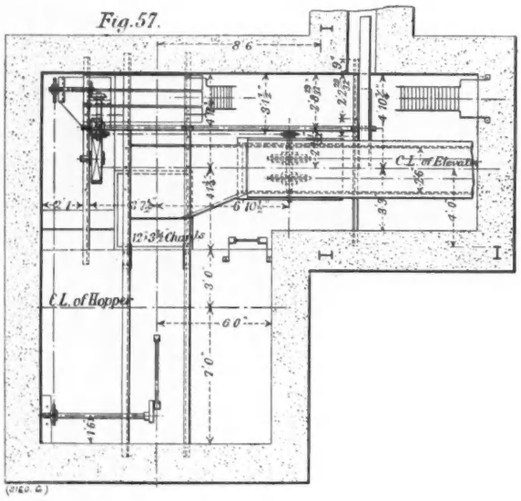


Fig. 60.

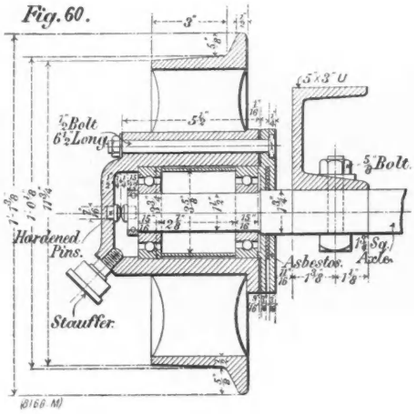


Fig. 71.

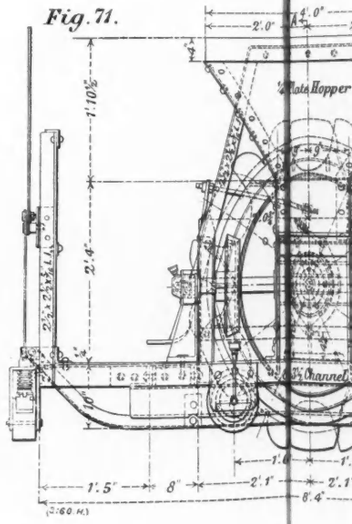


Fig. 58.

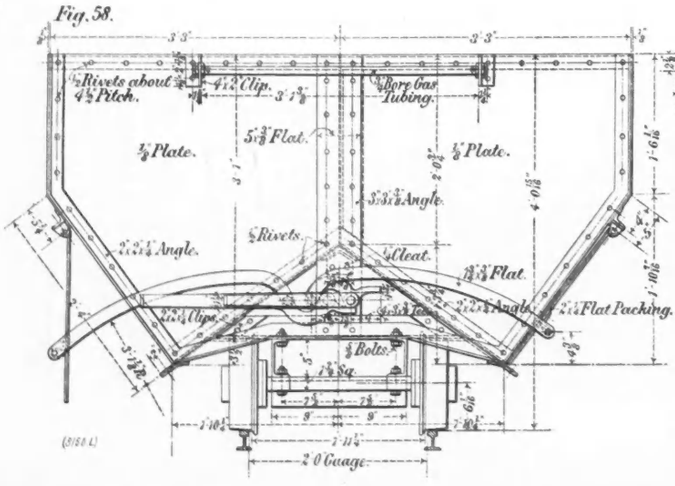


Fig. 59.

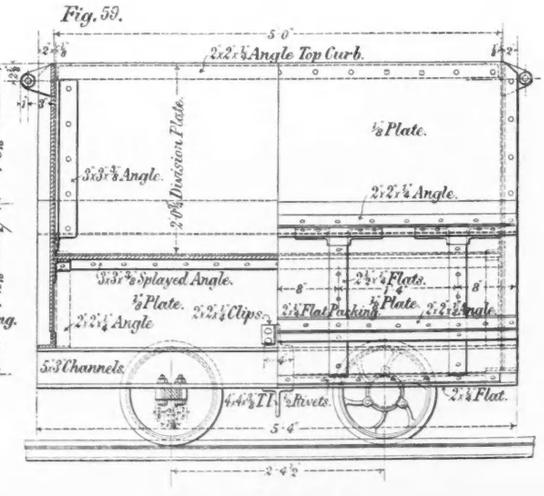


Fig. 13.

UOUS VERTICAL RETORTS AT SWINDON RAILWAY WORKS.

ER AND SO LIMITED, ENGINEERS, ELLAND, YORKSHIRE.

Description, Page 328.)

Fig. 62.

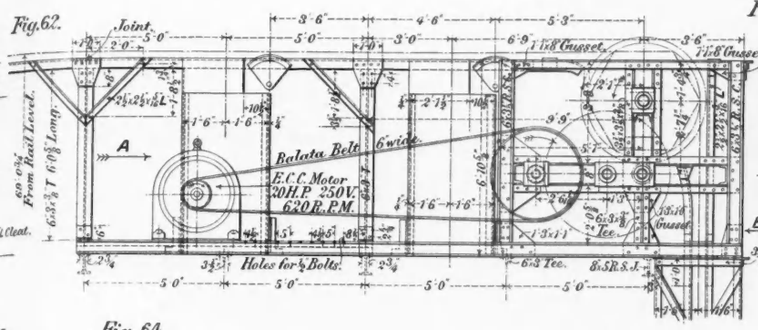


Fig. 63. ELEV. IN DIRECTION OF ARROW B.

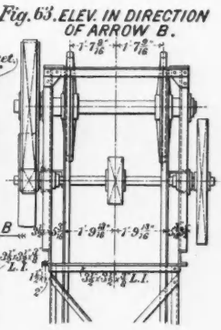
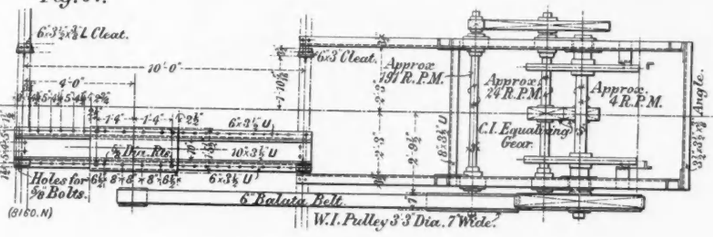


Fig. 64.



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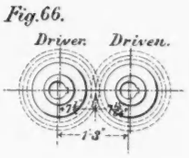

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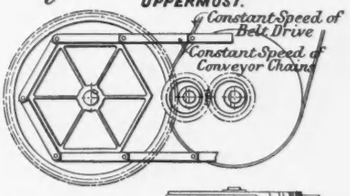

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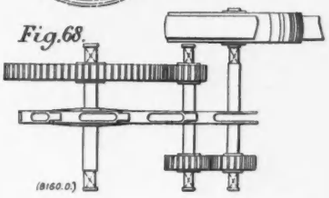

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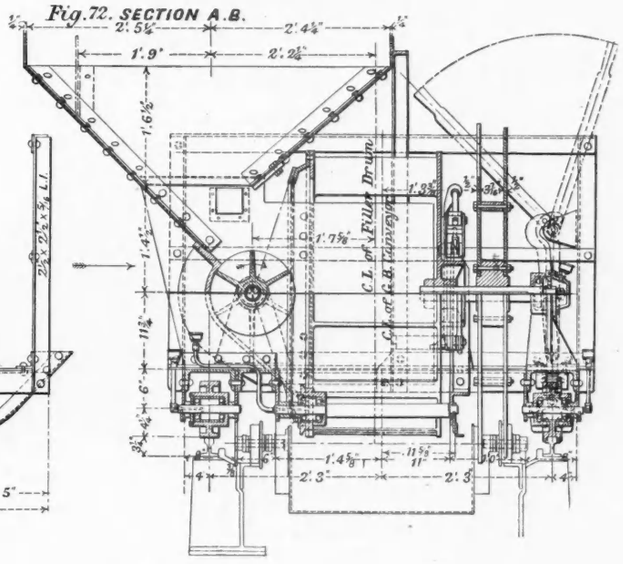

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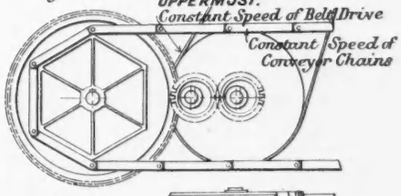

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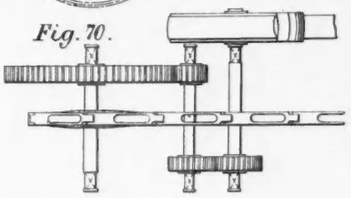

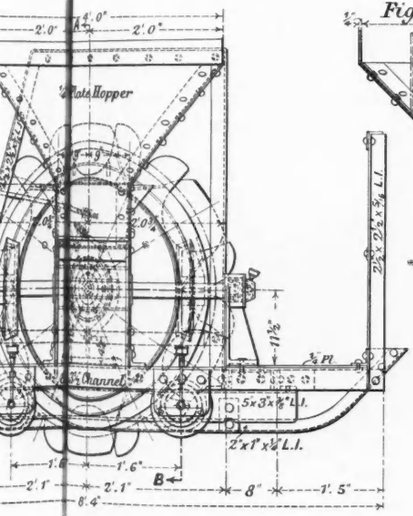

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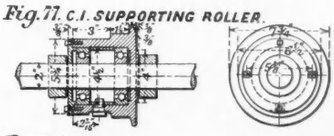

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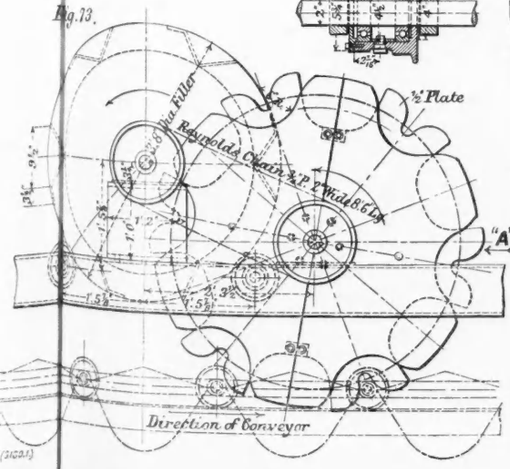

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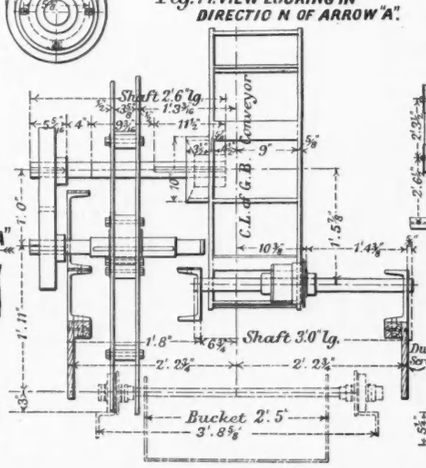

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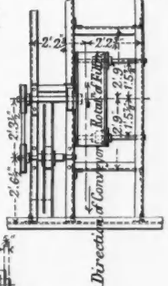

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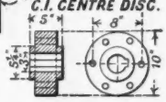

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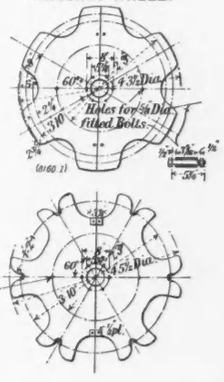

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ENGINEERING.

FRIDAY, MARCH 14, 1924.

ELECTRICAL METHODS IN IRELAND.

SOME 57 per cent. of the fuel requirements of Ireland are represented by imported coal, and it is matter of no surprise that during recent years considerable attention has been paid to the possibility of meeting part of the country's power requirements by hydro-electric development. The experience and example of our Dominions and of several Continental countries are available to show what can be done under favourable circumstances. The configuration of Ireland is very different from that of Norway and, although in the Shannon it has the longest river in the British Isles, it is probable that the general impression will be that there is no great potential water power available in the country. Apparently, however, there are greater possibilities than would generally be supposed and the Sub-Committee for Ireland of the Water Power Resources Committee, appointed by the Board of Trade in 1918, came to the conclusion that there was 500,000 water horse-power continuously available. No doubt much of this power is scattered over small falls, which would in the aggregate be expensive to develop, but apparently, there are possibilities of a valuable and commercially remunerative development on the River Shannon.

The river has been examined more than once from this point of view, and very extensive surveys were carried out in 1915 by Mr. Theodore Stevens for the Irish Hydro-Electric Syndicate in connection with the manufacture of ferro-chrome. He proposed a head-race below Killaloe and the diversion of part of the river, giving an available power station site with a head of 50 ft. The scheme promised an average of 17,000 horse-power throughout the year and 40,000 horse-power for some 20 weeks. In view of Mr. Stevens intimate knowledge of the river the Water Power Resources of Ireland Sub-Committee obtained his assistance in connection with their investigations, and an alternative scheme was drawn up which was considered more suitable for general power development. It proposed a series of comparatively inexpensive barrages with power stations constructed along the course of the river and was worked out on strictly commercial lines.

It was, of course, no part of the duty of the Water Power Resources Sub-Committee to take any steps directed to the actual development of the Shannon or any other river, but the report they were able to make was so promising that it is a matter for no surprise that the question has been taken up by the Government of the Irish Free State, which, under its constitution, claims the ownership of all such natural resources. The manner in which that government has seen fit to approach the question is, however, matter for very considerable surprise. It has entered into negotiations with Messrs. Siemens Schuckertwerke of Berlin, and has made that company an offer which gives it two chances of obtaining the contract for the whole of the development work, power houses, machinery, transmission lines, sub-stations, distribution systems and, indeed, apparently everything connected with the scheme. These two chances are to be given to the firm free of all competition and with no alternative quotations being obtained from any other firms British, American, Swiss or of any other nationality, competing firms from among their friends, the Germans, even being excluded. In addition to this the Irish Free State is to pay Messrs. Siemens Schuckertwerke 10,000*l.* for preparing the scheme.

Details of this remarkable and business-like offer are contained in an Official Irish White Paper, published last week, and that all sanity and sense of common fairness has not departed from our neighbouring island is made evident by an interview with Mr. L. J. Kettle, the City Electrical Engineer of Dublin and the Hon. Secretary of the Electricity Supply Association of Ireland, which was published in the *Freeman's Journal* last Monday. Mr. Kettle characterises the scheme as "the most amazing proposal that has been placed before the public for some time," and suggests that the proposals mean "nothing more or less than the granting of a monopoly to a certain firm for absolutely no value received." That these expressions of opinion by Mr. Kettle contain no exaggeration is made very clear by an examination of the White Paper.

It appears from information given in the *Freeman's Journal* that the gesture of fraternity which this proposal represents first began to develop some six weeks ago, when Messrs. Siemens Schuckertwerke sent Herr Reichard and Herr Wallem to investigate possibilities. Accompanied by Dr. Thomas A. McLaughlin, an engineering graduate of the National University, they visited the Shannon and made proposals, on which the offer from the Government is based. It will be noted that this party was apparently able to make up its mind about what could be done on the Shannon in a remarkably short time, but rather than accuse it of hastiness we prefer to believe that it had the advantage of being able to study the earlier reports of Mr. Stevens and others. It may be noted that one of the clauses of the official offer to Messrs. Siemens Schuckertwerke states that the Government is to provide the firm "with every facility in the way of information which it has at its disposal." We note from the covering letter from the Minister of Industry and Commerce directed to the Messrs. Siemens Schuckertwerke that "previous inquiries into the possibilities of the river Shannon for the purposes of hydro-electric development had results much less optimistic than those at which your firm has arrived." This, we think, is not remarkable. A manufacturing firm of any nationality which sees a possibility of getting a contract of the magnitude concerned here, with no competition, is likely to see the advantages which would follow the work being carried out in a somewhat rosy light.

We cannot find space to reproduce the whole of the proposals constituting the scheme which are published in the White Paper, but an idea of the more important ones will be sufficient to illustrate the nature of this altruistic offer which in a distracted world should bind at least two nations in happy union, even if it jars a good many of the others. The conditions are that Messrs. Siemens

Schuckertwerke are to work out a detailed scheme for the development of electric power from the Shannon and its distribution over the Irish Free State to sub-distribution points in various cities and towns. A binding estimate of the cost of the scheme is to be given, and the scheme is to be devised on the basis of proving a sound commercial proposition giving an adequate return on the capital invested in it. The scheme is to be produced by September 1 next.

When Messrs. Siemens Schuckertwerke's scheme and proposals have been presented the Government of the Irish Free State is to have power to submit them to expert examination from the technical and economic points of view and to undertake to employ experts of European standing for the work. If the firm is agreeable the scheme may be modified in the light of the reports of such experts. The scheme as finally determined shall then either be promoted by the Government as a State matter, or failing this, the firm will be given an option to carry out the work itself. In the event of the State promoting the scheme Messrs. Siemens Schuckertwerke would be awarded "the contract for the supply of all material and the construction of all works at world market prices." In addition Messrs. Siemens Schuckertwerke would prepare the specifications and plans and would be "paid a fee on the scale approved by the German Institute of Engineers." As will be seen this is very nice for Messrs. Siemens Schuckertwerke. Many manufacturers and firms of contractors at times do their own consulting engineering, but they are seldom lucky enough to be paid both as consultants and contractors.

If the Government does not proceed with the scheme itself, Messrs. Siemens Schuckertwerke, as we have said, are to be given an option to carry it out themselves. The firm would have to accept "all such statutory obligations as the law of the Free State may from time to time impose on public electrical undertakings." In other words, a foreign firm presented free with a concession for what may ultimately prove the control of the whole of the electrical supply of the Irish Free State would be required to comply with the laws of that State. This does not seem to be a very onerous condition. There is, however, a further condition which really has a little weight, and this is to the effect that if this offer is not accepted in a year it will be withdrawn. We have already stated that Messrs. Siemens Schuckertwerke were to be paid 10,000*l.* for preparing their scheme. This apparently is only in the event of neither the State nor the firm carrying it out. The White Paper is, however, a little obscure on this point, and in a later clause suggests that if the option is not exercised the sum will be reduced to 5,000*l.* This is no great matter either way, but is well in line with the sacrificial nature of the whole affair. Apparently no matter what happens Messrs. Siemens Schuckertwerke are to get at least 5,000*l.* for the pleasure of tendering for a job.

GENERAL AND LOCAL TAXATION IN RELATION TO ENGINEERING COSTS.

INASMUCH as the cost of unemployment is a burden which falls with greater emphasis on industry than on the rest of the community, and inasmuch as unemployment in the engineering industry has been particularly severe, we think it proper to give it prominence in our consideration of engineering costs.* There are, however, many other categories of sociological legislation already in existence which deserve attention. The importance of these categories is enhanced by the fact that there is an immediate prospect of their being extended in application and increased in number. Indeed it would be misleading to proceed with an attempt to assess the effect of general and local taxation upon industry in the coming year without first making some estimate of the additional burdens arising from this cause likely to be imposed in the near future.

No doubt many of the reforms which it is proposed to undertake will be to the ultimate benefit of the nation. It is not intended to argue that it is desirable or possible permanently to obstruct these reforms. It cannot, however, be ignored that the cost of carrying them out will fall principally upon industry, and it will fall in the near future, and at a time when industry is least able to afford it. Now when the financial and industrial position of the country is in such a precarious state it will make a very great difference whether these reforms are put in hand gradually, in such a way that industry can absorb the load, or whether they are made injudiciously, so as to swamp the industrial mechanism. It is very much to be feared that they will be put in hand too quickly.

For these reasons it is worth while to attract the attention of manufacturers to the prospect before them, and to suggest that it behoves them to be alive to the facts of the situation. Although the Minister of Health has been constrained to reduce his official housing programme from two hundred thousand working-class houses to one hundred and twenty thousand in the present year, it is unlikely that the cost of the programme, if fully carried out, will be less than 72,000,000*l.* This figure is based upon the Government's own estimate of the cost of building the houses, with a moderate allowance for the other incidental expenses besides the actual cost of construction.

Moreover, a further increase of two millions is to be expected from minor amendments to the Old-Age Pensions Act now under consideration. The Minister of Labour's estimate of the cost of the abolition of the "Gap" in the unemployment insurance scheme was half a million pounds annually, and this is certainly not an exaggeration. The amendments to the Workmen's Compensation Act, passed last year, when in full operation will mean an increase of not less than 25 per cent., or 2,000,000*l.* a year. The new Education Programme recently announced will cost 10,000,000*l.* in the present year, and will be a rising figure for many years to come.

The Chancellor of the Exchequer has to find a further 20,000,000*l.* for the extended Provision for Widows, to the principle of which the Government has committed itself. It would seem that the Chancellor seriously proposes to abolish the Entertainments tax at a cost of nine and a-half millions, while he can hardly fail to make a reduction of at least ten millions in the tea and sugar duties.

These items amount to one hundred and twenty-six millions sterling. Added to this will be the cost of measures under contemplation, of which the cost cannot at present be estimated. The principal items under this heading are the extended unemployment scheme so as to provide a higher rate of benefit, an increased number of benefit weeks in the year and the removal of the restriction from benefits to those whose unemployment is caused by a strike in which they are not participating. Further amendments to the Workmen's Compensation Act are to be expected, as well as extensions and additions to factory legislation, and an increase of safety precautions in mines. Altogether the increased expenditure will fall very little short of one hundred and fifty millions or 3*s.* in the pound on income tax.

As against this it would appear that the Chancellor will have a surplus of forty millions in the current year, and without increasing taxation might reckon on having a similar surplus next year. This is, however, a rather large assumption inasmuch as there will be three bad years in the assessment, and there will be a complete absence of those special contributions to revenue arising from levies on war wealth which have hitherto been of so much assistance to his predecessors. If, however, a substantial improvement in trade materialised, revenue might prove buoyant and fulfil his expectation. The scope for further economies is small, and the Chancellor would be fortunate if he were to have a surplus of seventy millions next year. Whether by any financial device he could meet his increased expenditure without a re-assessment of taxation this year must be a matter of considerable doubt; it will appear, however, that next year an increase will be inevitable if the Government receives its mandate from the country to carry out its full policy.

From these considerations, taken in conjunction with the summary of the unemployment situation contained in a previous article on page 308 *ante*, it will appear that there is very little prospect of a reduction in the existing burden of taxation, the probability being that we must expect an increase. Having made this clear, we may now proceed to a consideration of what the existing burden means in terms of standing charges upon industry.

Adam Smith has stated in his "Wealth of Nations" that "private revenue of individuals arises from three sources, rent, profit and wages. Every tax must finally be paid from some one or other of those three different sorts of revenue, or from all of them indifferently." Under the present system of taxation in the United Kingdom it is true, as a generalisation to say, that, rent and profits provide that portion of the revenue which comes from direct taxation, and which is contributed by Capital, while wages provide the revenue from indirect taxation, which is contributed by the workers. It is necessary to add in qualification of this, that capital pays one-third of the indirect taxation, and that a few highly paid workers contribute a certain amount to direct taxation. These items probably cancel each other, more or less, so that substantially the truth of the original proposition holds good.

We may, therefore, say that out of the total revenue raised by general taxation of seven hundred millions in the current year, approximately two hundred and sixty millions representing indirect taxation, is provided by the workers, and four hundred and forty million representing direct taxation is a standing charge upon industry. It may be further noted in this connection that out of a total population of 48 millions only 4,750,000 persons are assessable for income tax. Of these 2,500,000 are exempted by allowances and 2,250,000 actually contribute the revenue.

The total amount collected in local taxation in the year 1922–23 was 176,000,000*l.*, which is equivalent to 4*l.* 12*s.* per head—an increase of 120 per cent. over 1914. Apart from the gross amount of this sum the incidence of local taxation is particularly unequal for 82 per cent. of the total was collected in 1,154 urban parishes and 18 per cent. in 13,000 rural parishes. Inasmuch as urban parishes correspond to a great extent with industry, we have here an indication that industry once more is bearing by far the larger burden.

That is not all. In spite of the extension of the Unemployment and Health Insurance schemes, which has caused an increase in the contributions by industry of 328 per cent., as compared with 1914, industry's contributions to local taxation have also risen by 295 per cent. This fact was elicited by taking an extensive sample from industrial concerns throughout the country. In other words, not only is there normally a disproportion between the contributions of industry and those of the rest of the community, but also this disproportion has been accentuated during the last few years.

From the above summary, we may conclude that under the headings of general and local taxation industry has to find not less than 600,000,000*l.* a year, without making any allowance for the heavy transport charges of which the greater part fall upon industry. It is, however, impossible by this method to allocate to the engineering and allied industries as opposed to industry as a whole, their own particular share of this huge sum. Indeed, by no method could any really accurate estimate be obtained from the information at present available, but by approaching the question from another angle, bearing in mind the conclusions just reached, some approximation may be made. We shall therefore attempt to ascertain the number of persons more immediately concerned with engineering and to find the percentage of this number to the total population.

In doing so, it would clearly be inadequate to take only the employees of the industry itself and their dependents, inasmuch as the taxation which falls upon that part of the employees of secondary and primary processes which is normally engaged in producing for the industry, is reflected in the production costs of these processes and is in turn reflected in engineering costs.

As an instance of this, in the year 1922, 251¾ million tons of coal were raised, of which 64 million tons were exported. Of the remaining 187¾ million tons available for home consumption, 67 millions,

* See pages 273 and 308 *ante*.

or one-quarter of the total amount raised, was used by the engineering, shipbuilding and allied industries. It would appear, therefore, that it would be roughly true to say that a quarter of the coal miners are normally engaged in production for the engineering and allied industries. Applying this principle to other primary and secondary processes, and adding the number of employees so obtained to the number of employees shown in the Ministry of Labour *Gazette*, as directly occupied in the engineering, shipbuilding and allied industries, we get a total of 2,100,000 employees roughly as our basis figure. The average number of dependants per employee is usually considered to be three. Altogether, then, we might say that 8½ millions of persons out of a total population of 48 millions are contributing taxation which is reflected in engineering costs. The total general and local taxation having been taken as 876,000,000*l.*, over 17 per cent. of that sum, or 155,000,000*l.* per annum must be considered as a standing charge upon engineering costs. It will readily be appreciated that this is an extremely rough estimate, but it will serve its purpose if in conjunction with the forecast of probable increases in taxation made above it gives an indication of the direct effect which such an increase would have upon the industry, and also if it brings home some appreciation of the truth that under the existing system taxation in the main falls upon industry rather than upon other sections of the community.

It may be as well, however, to point out that this factor has two aspects. It follows from the fact that, while an increase in taxation would be directly of far-reaching bad effects, a decrease of taxation would give an immediate and corresponding stimulus. In the financial year 1921–22 the receipts from income tax were 398,000,000*l.* At the end of that year the tax was reduced by 1*s.* in the pound, and it was estimated that in the year 1922–23 it would only yield 329,000,000*l.* In actual fact it produced 379,000,000*l.*, showing how quickly revenue responds in increased buoyancy from the optimism felt by industry as a result of reduced taxation. If a reduction of 1*s.* in the income tax only reduced the receipts by 19,000,000*l.* instead of 69,000,000*l.* as anticipated, in the very depressed period to which we allude, there can be little doubt that at the present moment a similar or even smaller reduction would give such an impetus to trade that it might well get the country definitely out of the slough into which it has fallen, and very possibly would reward the Chancellor who had courage enough to make the reduction by giving him a larger revenue than he will get under the present assessment.

We would, therefore, urge manufacturers to realise how intimately their prosperity is connected with taxation. We would urge them to take any steps in their power to see that the true interests of industry, on which national well-being depends, are not lost sight of in the anticipation of legislation before its proper time. It is industry that has to make the money to pay the taxes. When industry has done this it will be time enough to consider these sociological problems. Also apart altogether from our internal affairs there is the question of out own taxation in relation to that of our competitors in other countries to be considered. With this and other factors in competitive costs we will deal in a subsequent article.

THE NAVAL BASE AT SAN FRANCISCO BAY.

THE report of Admiral Rodman's Committee on Fleet Bases was printed as an appendix to Mr. Secretary Denby's last annual survey of the naval administration of the United States. It was the second report of its kind; for, since the expansion of the United States navy, no problem has been more urgent than that of giving it fully-equipped bases from which it can operate in the Atlantic and the Pacific. Admiral Rodman recommended that two bases "capable of serving the entire fleet in every respect" should be set up in the Atlantic—one in New York-Narraganset Bay region, the other in the Chesapeake Bay; and that, on the Pacific coast, San Francisco Bay and Puget Sound should be similarly equipped. Another of these principal bases was to be erected in the Hawaiian islands; and there were to be secondary bases for light cruisers, flotillas and submarines at San Diego (California), in Alaska, in the Canal zone, and at four other places on the Atlantic side. The report estimated that the whole programme would be completed in 1944 and would cost roughly 155,500,000 dols. This gigantic scheme of naval development was laid before a committee of the House of Representatives early in February; and the discussions that it provoked are illustrative of the technical problems which surround the whole question of fleet bases and their security from attack. Up to now the parliamentary committee have only considered one item of the programme—that of making a naval yard at Alameda in San Francisco Bay, in addition to the one at Mare Island.

Admiral Eberle of the navy department has given evidence in support of Admiral Rodman's recommendations. His arguments are that the depth of water in the approach to Mare Island only allows capital ships to use it if they are "free of their coal and ammunition and most of their supplies"; and that the muddy water in San Pablo Bay, where Mare Island lies, will choke any ship's condensers in a few hours. He argues, moreover, that if Mare Island is maintained as the only navy yard in San Francisco Bay, the existing wharves and facilities at Almeda will be wasted. He further points out that it is not proposed to put the Mare Island yard out of commission, but only to keep it for repairing lighter ships and for making machinery. It was on this point that Admiral Eberle's answers were a little puzzling. There are eight dry docks and four slips in San Francisco. Of these, Hunter number 2 (750 ft. over all, and 71½ ft. on the blocks); and Mare island number 2 (740 ft. over all and 713 ft. on the blocks) can accommodate the largest ships in the American navy. The remaining docks and cradles vary from 416 to 161 ft. over all, and are all more or less suitable for repairing small ships. Why, then, should Admiral Eberle state that Mare Island was to be used for the repairing of small vessels, when it is obviously one of the two places in the bay where large ones can be accommodated for a refit?

The remainder of the admiral's evidence was most significant. In answer to a question from a member of the committee he admitted that 700 vessels, large and small, would have to be accommodated and kept in full commission on the Pacific coast in the event of war. In addition to this, a member of the committee made the grave statement that, in his opinion, the Pacific coast of America was likely to become the theatre of the most titanic struggle that history will ever have to record. A naval effort of such intensity will strain the available resources at Puget Sound, Los Angeles and San Diego to the uttermost; and as San Francisco with its ten docks will be the most important of all the Pacific bases, no half measures with regard to its development will suffice. Admiral Eberle did, however, admit that if a 30-ft. channel between Mare Island and the deep parts of San Francisco Bay could be dredged and maintained, naval experts would be contented.

The arguments against developing Alameda seem equally strong, and may be summarised as follows: The defensive strength of San Francisco harbour consists in its narrow entrance, which can easily be defended by permanent fortifications; in its comparatively shallow approach, which makes it easy to defend it by huge minefields outside the Golden Gate; and above all, in the high land between the sea and the inner harbour, which forms a protective bastion for San Pablo Bay and the Carquinez narrows. On the other hand, this high land does not shelter all parts of the bay to an equal extent; and the wharves and docks at Alameda and Oakland would be exposed to bombardment from the sea, whereas those at Mare Island would not. Alameda might be tremendously damaged by vessels firing at it from a distance of 25,000 yards; for, at such a range, the trajectory of their projectiles would be high enough to carry them over the comparatively low land to the west of Hunter's Point, and make havoc of the new navy yard. Naval experts argue that such a thing would be disastrous, as it might completely dislocate American plans for mobilisation at the very outbreak of war, and give the enemy an initial advantage which it would be very difficult to recover from him. They urge, moreover, that it is the kind of operation which the Japanese navy would exert itself to the utmost to perform. Japan has always begun her wars with a furious naval onslaught; and if the Rodman project of setting up a new navy yard in a particularly vulnerable spot is adopted, the Government will simply play into the hands of a prospective enemy. Those who hold these views support them by reference to the Japanese cruisers of the Kongo type, and say that these ships, with their speeds of 27 knots, their 4,000-mile radius of action and their eight 14-in. guns, are specially adapted to offensive operations overseas.

The discussion is thus a most instructive example of the difficulty of adapting maritime resources, which nave been amassed for the purposes of trade and industry, to naval uses. Judged by existing facilities, Alameda is far superior to Mare Island. The Southern Pacific railway runs in at Oakland, which is also connected to Stockton, a nodal point in the southern railway system, by a line running along the southern bank of the San Joaquin river, through Martinez and Richmond. It is quite true that Mare Island is joined up to the central Pacific railway system at Sacramento, but the carrying capacity of the Mare Island railway is said to be far lower than that of the Oakland system. These factors seem to weigh heavily with the naval experts. One of the principal points in the Rodman report was that the degree to which naval bases would extend in war time was incalculable, and could only be provided for by ensuring that they were connected, as closely as strategical desiderata admitted, to the country's industrial centres, and so placed that the resources of the great shipbuilding yards were at all events within easy reach.

VOCATIONAL TRAINING FOR MANUAL WORKERS.

A REPORT on vocational training for manual workers in the engineering industry has now been issued by the Association for Education in Industry and Commerce.* It is the result of a reference to the Association's local committee in Glasgow, and has been prepared by representatives of Messrs. William Beardmore and Co., Limited, Messrs. Barr and Stroud, Limited, the Albion Motor Car Company, Limited, and Messrs. G. and J. Weir, Limited. The intention of the reference was not to add to the various reports that had been made on the general and technical education of engineers—in the context professional engineers seem to be meant—but to deal mainly with the training of manual workers to be good and skilled craftsmen, including training in manipulative skill and instruction in the principles that underlie manufacturing processes.

To ascertain what has been done in the matter already a questionnaire of some 28 points was sent out to manufacturing firms, with the object of learning how far traditional apprenticeship had been replaced or supplemented by other training; where, how and in what branches of work such training was given; whether it was purely manipulative, or extended to the principles underlying workshop methods and the solution of workshop problems; what sort of results had been obtained, and what improvements were contemplated; how progress was measured and encouraged; and how far the work was or could be done in technical schools and colleges. No information is given as to the number of firms questioned or as to the number who replied, except that the number of replies was not so great as had been expected, and included a number of firms who gave no organised training whatever.

More than half the firms who have replied—it is a little tantalising not to know even about how many—entrust the duty of preparing and supervising training schemes to some special person or persons; either the works manager, the welfare supervisor, a whole-time supervisor of apprentices,

* Copies (price 1*s.*) can be obtained from the Honorary Secretary, Mr. R. W. Ferguson, 36, Linden-road, Bournville.

or a works committee on which both the management and the men are represented. Most firms give the training in the ordinary manufacturing departments, one in its several tool-rooms (apprentices being moved from one tool-room to another in the course of their time), and a few in special departments set aside for the purpose, where the persons under training are engaged on manufacturing work and not on mere exercises, and remain there for from three to twelve months. The range of trades in which training is being given in one or other of these ways includes fitting, turning, machining, smithing, pattern making, moulding, brass moulding, painting, motor body building, armature winding, millwrighting, tool fitting, boilermaking, plating, riveting, coppersmithing, sheet metal working, trimming, and electric wiring. In addition to instruction in manipulation some firms also teach the principles underlying the manufacturing processes, either individually in the workshops, collectively in lectures, or partly by one and partly by the other method. With one exception, in which trade tests are held, the only tests of progress by those firms who make them are written examinations, dealing mostly with technical knowledge. Various inducements to progress are offered in the way of prizes or promotion.

All the opinions expressed concur in thinking that technical institutes, however equipped, cannot reproduce works conditions or give practical training as effectively as it can be had in the workshop, though advantage is found in their teaching of subjects such as mathematics and mechanics. Few institutes give instruction in the principles of workshop practice, and opinions are divided as to whether those who are to remain manual workers derive benefit from the scientific teaching they get there.

The general view indicated by the replies is that boys now require some form of training other than apprenticeship of the old type, and that this training should be supervised by some definite individual. The system must vary widely with the works. On balance it is thought that the principles underlying workshop methods can be taught by lectures and demonstrations given collectively, especially if the instructor actually carries out the process after he has given his explanation, but that technical institutes cannot replace workshops for training. The report points out that, while such institutes can neither provide the economical atmosphere of workshop manufacture nor the company of workmen in the shops, both of which are essential elements of a man's training, they can make good use of well-equipped workshops as a valuable help in demonstrating the principles of practice.

A short account is given of American experience, which has gone considerably further than British in making provision for training. The figures, however, which the report omits, show that in most establishments the training in question applies only to a small fraction of the workers employed. In the East Pittsburg works of the Westinghouse Company, for instance, which the report quotes, there were in 1920 under 200 four-year apprentices out of 18,000 to 20,000 workers; in the Schenectady works of the General Electric Company, employing about the same number, there were 328 apprentices of all sorts; the Detroit works of the Ford Motor Company employed 55,000 men, including 3,500 tool and die makers and 1,200 machine repairers, but their apprentices were only 1,000 in all, and, apart from the Institute in which expressly they were intending to train technical engineers, they had only 300 boys as trade apprentices. Even the Brown and Sharpe Company, in spite of their special need for workmen of the best class, had in 1920 only 200 apprentices out of their 7,000 to 8,000 men.

The report gives a number of general conclusions and recommendations, outlining methods by which training can be given in the works. No doubt can be felt that old methods of training are inadequate in modern conditions. Far more is known now of the principles on which practice is founded, and those who are learning the full skill of the engineer's craft should be taught what is necessary for them to know in order to do their work with intelligence, and to take such suitable opportunities of promotion as may come their way. By means of improved tools, again, a man can do far more in a shop as a machine hand with a very short training than was possible formerly, and his training should extend to a reasonable variety of machines, so that he can offer a corresponding variety of abilities, and increase his chance of employment proportionately. But when all allowance has been made for these necessities, the essence of a man's training will still have to be given in the workshop, and the Association will be doing good work if it induces firms to lay themselves out to give it. Such training is being given increasingly by works in other countries, whose engineering industries are as advanced as our own; and sooner or later it will have to be given here, if the relative quality of our workers and our work is to be maintained.

THE AIR ESTIMATES.

THE uneasiness aroused by the recent rather pacifist attitude adopted by the Under-Secretary for Air, as mentioned on page 234 *ante*, will be somewhat allayed by the Air Estimates issued on Friday last, which indicate that the Government have, in most respects, adopted the programme of their predecessors for the moderate and necessary expansion of the Air Force. The total estimated expenditure for the ensuing year is given as 19,392,000*l.* gross, and 14,511,000*l.* net, the latter figure being 2,500,000*l.* in excess of that for the current year. The provision for war liabilities in the new estimates, however, is only 185,000*l.* as compared with 525,000*l.* in the current year, the difference of 340,000*l.* bringing the increase in the net expenditure on the effective services to 2,840,000*l.* Actually the orders to be placed for *matériel* during the coming year will amount to 4,500,000*l.* According to the memorandum accompanying the Estimates, this sum will be mainly allocated to the expansion of the Air Force for Home Defence, to the increased requirements of Navy and Army co-operation work and to the replenishment of the stock of technical equipment.

During the year covered by the new Estimates, eight new regular squadrons for home defence will be completely formed, which will bring the total number of squadrons for that purpose to 18 by April of next year. Provision is also made for the initial equipment of six additional squadrons which will be completed in the following financial year. The total number of squadrons contemplated in the full programme is 52. The air units for naval work will be increased by five flights, the additions being due partly to the increased number of aircraft carriers and partly to the provision of aircraft to be carried in capital ships and cruisers; the units working with the Army at home will be augmented by the equivalent of one squadron.

The *personnel* of the Force will be increased by 2,000 to 35,000 during the coming year, but in accordance with the expansion scheme, already approved, the latter figure will eventually be raised to 40,000. The net estimate for works, buildings and lands amounts to 2,127,000*l.* as compared with 1,799,000*l.*, the figure for the current year. Under this heading is included the cost of constructing an additional wing at the Aircraft Apprentices' Training Establishment at Halton, which will increase the capacity of that establishment from 2,000 to 3,000. This is obviously necessary to provide the required number of skilled mechanics for the augmented force.

The vote for technical and warlike stores, with which is included the expenditure on the experimental and research services, stands at 5,700,000*l.* net estimate, this figure showing an increase of 1,832,700*l.* in comparison with the corresponding estimate for the current year. Although the reconditioning of existing machines and engines is being continued under this heading, it is particularly satisfactory to note that it is proposed to equip the new squadrons with machines of a new type. We trust that the re-equipment of the whole force in this way will be carried out with as little delay as the financial position of the country will allow, as the general efficiency of the air arm is obviously largely dependent upon the employment of *matériel* of the highest possible quality. To secure this, there must, of course, be no relaxation in the activities of the experimental and research establishments, and it is to be hoped that the decision previously announced (see page 116 *ante*) to place purely scientific research and technical development under the control of two separate directors will result in increased efficiency in this very important branch of the service. We understand, from the statement of the Under Secretary for Air made in the House on Tuesday last, when the House went into Committee of Supply on the Air Estimates, that three new types of machines for naval co-operation work are to be used, and that new types for Army co-operation are being developed. A new type of air-cooled engine is to be tried this year, and another will be tried later. A new type of water-cooled engine, he added, was being tested, and experiments were being made on a large scale in connection with the metal construction of aircraft.

The vote for civil aviation has been increased from 287,000*l.* in the current year to 355,000*l.* in 1924-25, but the last-mentioned sum is lower than might otherwise have been the case owing to the proposed formation of the Imperial Air Transport Company, the organisation of which was explained on page 21 *ante*. The increase in the estimates for the ensuing year is largely due to the proposed extensions to the Croydon aerodrome in accordance with the recommendations of the Civil Aviation Advisory Board, a sum of 120,000*l.* being allocated to this work in the ensuing year. There is no provision in the estimates for the development of airships, and it is in this respect that the Government's air policy differs from that of the previous administration. The Burney airship scheme has not yet been adopted although it has been favourably reported on by several different committees. Actually, it appears, a new committee has been appointed to investigate the matter further and this, of course, will delay the final adoption of the scheme, even if the committee eventually expresses its approval.

No one, we imagine, will regret the proposed further reductions contemplated in the Air and other Forces in the Middle East, which will reduce from 5,040,800*l.* to 3,708,850*l.* the contributions to be made by the Colonial Office from the Middle East votes to the air votes in respect of the cost of the Air Force and ancillary services. Of the sum to be contributed, over 3,000,000*l.* will be in respect of Iraq and the remainder in respect of Palestine and Transjordania. The Memorandum concludes with a warning to the effect that, as the Air Force expands and as the stocks of equipment accumulated during the war become obsolete, the total Air Estimates are likely to increase in future years, but this, to some extent, is offset by the fact that the capital cost of land and buildings and the first cost of equipment for the new squadrons will not be recurrent unless further expansion than that now contemplated becomes essential.

MACHINE DESIGN AND OPERATION.

AN important step has been taken in the proposal to investigate the design of machines with special regard to the convenience of their operation. The project appears first to have been broached in the last annual report of the Industrial Fatigue Research Board, and in an Appendix to that document Mr. H. C. Weston gave examples, taken largely from the Board's own work in various industries, of machinery that by its design was inconvenient and even mischievous to the operators. It was recognised that while from one point of view such an investigation must depend essentially on physiological work, from another it must no less essentially be mechanical, if its results were to have any practical value. Accordingly, the Medical Research Council, of which the Board is a branch, has arranged with the Research Department to set up a joint committee to supervise the Board's enquiry into the subject. Professor E. P. Cathcart, the Professor of Physiology in the University of Glasgow, has been appointed to conduct the physiological part of the investigation, and Mr. L. A. Legros, with the assistance of Mr. Weston, to conduct the mechanical part. On

the joint committee Professors Starling and Cathcart, as physiologists, Mr. D. R. Wilson (the Secretary of the Board) and Dr. G. H. Miles (the Assistant-Director of the National Institute of Industrial Physiology) represent the Council or Board, and Sir John Dewrance, Sir Joseph Petavel, and Engr.-Captain Roberts (Admiralty) represent the Department. It is intended that the physiological and the mechanical work shall proceed simultaneously and be carried on in direct and close co-operation, beginning probably with a survey of a number of machines in common use, with the object of selecting those that are most suitable for intensive study.

As has been pointed out repeatedly in these columns, investigations of problems of industrial fatigue can at best be partly successful, and are more likely to be wholly futile, unless persons familiar at first hand with industrial practice as well as with scientific method are concerned in planning and conducting them. In selecting Mr. Legros the authorities concerned have made an appointment that will secure the aid of an engineer whose exceptionally varied practical experience will be of much value and will assist in ensuring that, while on the mechanical side full, sympathetic and intelligent application will be given to physiological results, due regard will also be paid to industrial and mechanical circumstances.

It may seem paradoxical that, although labour is the largest item in engineering costs, and the well-being and contentment of workers is recognised as indispensable to satisfactory working, engineering manufacturers often look askance at investigations such as those of the Board. Yet there has been a good reason for the paradox. The mechanism of manufacturing industry is complex, and contains much that cannot be investigated in a laboratory; and neither can laboratory results be applied to works practice, nor even can conclusions be drawn from observations made in the works themselves, unless the results and the observations are viewed in an accurate perspective with the circumstances of works and workers. That is where practical experience becomes indispensable to useful inferences from scientific results or observations, and hitherto there has been little evidence of such experience in the work that has been done on the economical use of human energy, or—which is often the same thing—the avoidance of fatigue. It may be hoped that the organisation of the investigation under notice will mark the beginning of a new stage in such work, and show the way in which industry may really assimilate and profit by scientific research on matters that affect its workers.

NOTES.

The Water Supply of Rural Districts.

The provision of a water supply for a small community involves problems quite different from those experienced in dealing with large urban districts. Not only are the questions which the engineer has to deal with of essentially different characteristics but there are other dissimilarities in connection with the grant of legal rights, administration and finance. In a paper read before the Institution of Sanitary Engineers on March 5, Mr. Cecil H. Roberts, M.Inst.C.E., referred to these problems and discussed the manner in which some of them may be met. The great legal difficulty involved in water supply for rural districts was that the council had no power to charge the rates with the expense of promoting a Bill in Parliament. In some cases a risk had been taken by certain rural district councils, and Bills had been promoted in which provision was made that the council received permission to charge the expenses to the rates. Such actions had, however, only been undertaken when the rural council was confident that the proposals submitted would pass, for otherwise they would have to meet the expense in some other way. In this respect the urban councils suffered no cramping restriction. Rural councils did sometimes obtain piped supplies of water from a water company or a local authority. These endeavours had, however, proved unsuccessful when it could be shown that a satisfactory supply could be obtained locally at less cost than that necessary to lay a long pipe from the nearest main of the water company. The authority was generally obliged to supply under certain conditions if the cost of laying pipes did not exceed ten times the annual water rate receivable. Some modification of this had been seen in private Acts in recent years, in which the cost figure was increased from 10 times to 16⅔ times the annual water rate. One of the great advantages of combined schemes was that the source of supply and the principal works could be more economically and efficiently looked after than could a number of small works in different parishes.

The Engineer and the Petroleum Industry.

Before delivering his presidential address to the Institution of Petroleum Technologists on Tuesday, March 11, Mr. Herbert Barringer made the announcement that Mr. Alexander Duckham had presented a medal to the Institution to be known as the "Redwood Medal," which would be awarded to the reader of the most outstanding paper of two succeeding sessions. The engineer had played such a conspicuous part in the development of the petroleum industry that the selection of the title of this note for the presidential address must be commended. Mr. Barringer surveyed the whole field of the work of the engineer in this phase of activity from the early surveying to the transport of the oil. After briefly dealing with the rotary system of drilling and its most modern arrangement, the double tube equipment ensuring effective water circulation, the president referred to the percussion method of working with connecting poles or cables, as used in the Canadian and Pennsylvanian processes. The expense of running, which was experienced when steam was used for the provision of power in the oil fields was considerable, owing to the long length of inadequately lagged pipes and the lack of economy of the engine. When electric driving from a power supply was possible great gains were obtainable and the difficulties of transporting heavy prime movers were eliminated. There was, however, some disadvantages in actual boring by means of electrical power owing to the difficulty of obtaining instantaneous variations of speed within wide limits, but there were hopes that these troubles would eventually be completely overcome. In some cases the use of oil engines with direct transmission of power was possible. Pumping through pipe lines was the most convenient, and in many cases the most economical means of transport, but there were conditions when the use of rail tank wagons or barges was necessary. When pipes were in use spring scrapers, known as "Go Devils," were often pumped through them with the oil, to remove any deposit. Duplex direct-driven pumps were most favoured in the handling of oil because of their flexibility, ease of handling, reliability and the steadiness of their discharge. Viscosity played a large part in the resistance to flow but could be greatly reduced by raising the temperature.

Workmen's Compensation—Fluctuations in Wages.

General fluctuations in wages sometimes give rise to difficult questions with regard to the amount of weekly payments. There have been cases in which men who have been in receipt of weekly payments in respect of partial incapacity have claimed an increase in the weekly payments because owing to the general fall in wages the difference between their earnings and their pre-accident earnings has been increased. It has been held that in such cases a fall in earnings due to a general fall in wages is no ground for an increase in the amount of the weekly payments. On the other hand there is a case in which a man who was a miner before being injured had to take work as a clerk under a local education authority because he was unable, owing to his injury, to continue at his former work. The local authority subsequently lowered the wages of its officials, and the man claimed an increase in the amount of his weekly payments of compensation. There was no evidence that if he had remained a miner there would have been any reduction in his wages. He was held to be entitled to an increase in compensation. The case of McCombe against the Bent Colliery Company, of Bothwell, which was decided by the Court of Session in Edinburgh on March 1, lay half-way between these two classes of cases. A man had been a pony driver at a colliery before his accident; afterwards he was given light work as a picker at the same colliery. Some time later his wages were reduced in consequence of a general fall in wages, and he claimed an increase of compensation. The Sheriff-Substitute at Hamilton—who corresponds in many ways to an English County Court Judge—held that he could not review the compensation. On appeal by stated case the Court of Session held that he was bound to review the compensation. The man's grade of employment before the accident was different from his grade of employment after the accident, and his wages were higher, and had he not been injured he might not have been affected to the same extent by the slump in wages, because the datum lines of his previous and his subsequent occupation were different. The Court agreed that where economic causes are the sole cause of the reduction in a man's earnings there is no right of review, but where economic causes plus injury by accident combine to bring about the reduction there is always a right of review. It was for the Sheriff-Substitute to discover the two causes as best he could and determine to what extent the diminution of the man's wage was due to his injury, and to what extent it was due to economic causes. The case was accordingly sent back to the Sheriff-Substitute in order that he might apply his mind to these difficult questions.

Alloy Plating.

Rapid advances have been made in the deposition of metals in the electro-plating industry, and in the spheres of electro-metallurgical extraction and refining. The subject of alloy plating, however, although possessing great possibilities, has not received the attention it deserves. A considerable amount of work has nevertheless been carried out on the electro-deposition of brass, and in his lecture on "Alloy Plating" to the Sheffield section of the Institute of Metals on the 7th inst., Mr. S. Field dealt with the subject. He stated that when an acid solution of mixed sulphates of copper and zinc was subjected to electrolysis, the copper was entirely deposited on the cathode, leaving the zinc in solution. The question, therefore, was to ascertain means by which both metals could be deposited simultaneously with the same ease, and this actually resolved itself into finding a solution so electrolytically stable that both metals were deposited equally. Double cyanides of copper and potassium, and zinc and potassium, fulfilled these requirements, and solutions of these salts were used in brass plating. The composition of the deposited metal was important, and an approximate computation of this could be calculated from formulæ based upon the relationship which existed between the weight deposited and the coulombs of electricity expended. The "throwing power" of electrolytes, *i.e.*, their ability to cover irregular surfaces with a uniform film was a most important point. The cyanide solutions of copper and zinc possess good "throwing power," and this was due to their electrolytic stability. The readiness with which copper was deposited from acid solutions gave the latter a poor "throwing power." Mr. Field briefly alluded to various other alloys which had successfully been deposited by electrolysis. A certain amount of bronze plating had been done, he added, by using electrolytes consisting of double oxalates of copper and tin. Lead and tin were metals which were not ordinarily deposited electrolytically; yet, by using solutions consisting of fluo-borates, excellent deposits of an alloy containing 37 per cent. of tin and 63 per cent. of lead could be obtained. The United States Navy Department had utilised this alloy for coating various internal parts of torpedoes. The lecturer also mentioned, among others, the iron-nickel series, and stated that the deposition of alloys of this type might play a large part in counteracting corrosion. With regard to the production of "stainless" coatings, as ferrous salts were always used in depositing iron, and chromic salts in depositing chromium, he could not, at present, see how it would be possible to obtain iron-chromium alloys electro-chemically. In conclusion he stated that closer collaboration and

co-operation between alloy platers would go a long way towards solving the many difficulties with which they were confronted.

THE INSTITUTE OF METALS.

THE sixteenth annual general meeting of the Institute of Metals was opened on Wednesday morning, the 12th inst., in the Institution of Mechanical Engineers, Storey's Gate, Westminster, the chair being taken at the outset by Mr. Leonard Sumner, the retiring president.

REPORT OF THE COUNCIL.

The report of the council on the work for the past year was read by the secretary. The report stated that, notwithstanding the continuance of severe trade depression, the membership had increased from 1,436 to 1,531, the growth of 95 being above the average for the past five years. The number of papers offered had been larger than ever before; in fact, more papers had been offered than could be accepted. Though papers by research workers were important, the council now, as always, welcomed what had been termed practical papers, provided they attained a sufficiently high standard. The Institute now had six local sections, the one latest formed, at Swansea, counting 30 members and 50 associates. The Institute is co-operating with other London technical societies in making arrangements for the first Empire Mining and Metallurgical Congress, to be held at the British Empire Exhibition on June 3 to 6, and the council hopes the members will support the congress by their presence and financial contributions. The Institute is arranging an exhibit at the invitation of the Non-Ferrous Metal Trades Joint Exhibit Committee.

Towards the close of the year the council learned from the Department of Scientific and Industrial Research that the grant made by the Department towards the cost of corrosion researches would be discontinued as from the 31st inst. The Department has made arrangements for the work to be continued under the direction of its own committee. It is understood that the services of some of the Corrosion Research Committee's investigators will be required in connection with the new work.

The council had considered a scheme for sharing with certain other allied institutions a portion of a large, new, centrally placed office building, but were unable to proceed with the scheme, owing to the increase in expenditure involved.

HON. TREASURER'S REPORT.

The report for the financial year ended June 30, 1923, showed against a deficit of 265*l.* the value of a considerable stock of volumes of the Journal, worth over 5,000*l.* on a conservative estimate. Nearly 50 per cent. of the Institution's income was spent on the Journal, and the report proposed to supply unbound volumes gratis to members, and to make a charge of 4*s.* per annum for supplying bound copies.

THE PRESIDENT'S ADDRESS.

After the reading of the reports, Mr. L. Sumner vacated the chair in favour of the new president, Professor T. Turner, and a hearty vote of thanks to the retiring president having been passed, Professor Turner proceeded to read his presidential address. In this he recalled that the first meeting of the Institute was held early in 1909, and thirty volumes of the Journal had since been issued, covering the work of fifteen years. The Institute was not so much concerned with the production of metals as with their subsequent manufacture, treatment and use. It was clear, however, that the supply of the raw material must be of primary interest to any industry, and in this connection Professor Turner mentioned the present visible supplies of a number of different metals and the rate of consumption per annum, adding that the future of the non-ferrous industry depended upon the extension of scientific knowledge in the direction of broadening the source of supplies, diminishing the cost of extraction, improving the methods of treatment, reducing corrosion and waste and dealing properly with the residuals. These matters formed the subject of scientific research by a number of prominent men and research associations throughout the world, and they had received the very careful attention of the Institute of Metals, one of whose most important functions was the publication of its Journal, which contained the latest discoveries in science and improvements in practice. On the Journal the Institute spent half its income, as stated by the hon. treasurer, whilst the management expenses were unusually low when compared with those of other similar bodies. There were two chief ways by which the value of a scientific journal might be judged: by its outside sales and by the readiness with which authors communicated their results for publication in its pages. Last year the sales to non-members realised more than 1,000*l.*, whilst the number of papers offered for publication had been considerably in excess of what could be accepted. The Institute, as a relatively young body, suffered from the disadvantage that it had no investments corresponding to those of larger and older societies dealing with other branches of work. It had to face not merely the increasing cost of publication, but with the larger membership and a growing library, additional accommodation would soon be needed and expenditure must increase. An endowment would be of the greatest possible value, and if there were any members or friends who were seeking an investment which would provide permanent and welcome aid to science and to the non-ferrous metals industry in particular, Professor Turner trusted that they would remember the claims and necessities of the Institute of Metals.

THE BRITTLE RANGES IN BRASS.

The first paper taken on Wednesday morning was entitled "The Brittle Ranges in Brass, as shown by the Izod Impact Test." We reproduce this in abstract on page 350 of the present issue.

Professor Turner called the attention of the meeting to two diagrams on a large scale and in colours, clearly showing the brittle ranges of annealed brass and those of chill cast brass.

Mr. T. G. Bamford stated that manufacturers would agree that the author's paper was of a practical nature since it has brought out facts which were known in the trade and confirmed them, thus giving confidence in regard to other points referred to also by the author but which were not so well known. The application of the Izod test in this connection was somewhat novel, but the method followed appeared to define brittleness well. The author had referred to former work by Edwards and Herbert and by Doerinckel and Trockels, adding that their results were not comparable with his own, but he (the speaker) found that those results confirmed those of the author's in some respects, as could be seen by the micrographs in the paper showing the cracks and fractures. The method of developing a fracture electrolytically was a very ingenious one.

Dr. O. F. Hudson found that the author had shown in a simple way the temperature ranges over which brasses were brittle, and had expressed in a clear way the results found, by contour lines in his diagrams and by statements in his paper. He (the speaker), however, believed that some of the results marked in the diagrams might perhaps not so much indicate brittleness as a certain degree of softness. The author had referred to this point and the speaker would have been glad had those particular results been omitted from the diagrams. With regard to the heat treatment given to annealed alloys, the author did not mention the rate of cooling adopted, and the point was one of some importance; it would have been advisable to vary the heat treatment according to the composition of the different alloys. The author had only dealt with pure copper-zinc alloys, and if he were to continue the work, the effect of impurities should be investigated, also the effect of added metals, and the brittle range of alloys worked and fully annealed.

Dr. Rosenhain missed in the paper the analyses of the brasses experimented with; very small proportions of impurities exercised an influence on the intercrystalline boundaries and affected the phenomena studied. This point had a very important bearing on the subject. It was not safe, Dr. Rosenhain added, to correlate Izod figures with brittleness, since mere weakness gave low Izod figures. The author should therefore explain what he meant by "brittleness." It was formerly very difficult to decide when a fracture was intercrystalline or intracrystalline; he (the speaker) had introduced the electro-depositing method referred to in the paper and by a former speaker, which greatly facilitated a decision on the point.

Dr. Haughton thought the author would be well advised to carry his work into the gamma region, *i.e.*, right to the end of the region where brittleness occurred. The author had stated that from 60 per cent. to 70 per cent. of copper, chilling had no effect on the lower limit, with the exception of a sharp fall which occurred between 63 per cent. and 65 per cent., *i.e.*, at the point where the alpha phase was entered; that was evidently due, the author added, to the final disappearance of beta from the structural composition. Dr. Haughton could not follow this statement and hoped the author would elucidate it.

Mr. T. H. Turner gave details of the work which the author had carried out single-handed, leading up to the paper then before the meeting. All this work could be gone into by manufacturers without the necessity of putting down new plant.

Dr. L. Aitchison congratulated the author upon adopting the Izod test at high temperatures; this had been done many years ago for testing steel at high temperatures. It was likely that a large amount of information regarding brittleness would emerge on following up the author's experiments.

In the course of his reply, Mr. Bunting said that the rate of cooling he had worked to was from 700 deg. C. down to 200 deg. C. in the space of 15 hours. He was continuing his investigations from the point of view of the impurities in brasses. He had not the analyses of his specimens after casting; the paper gave only the analysis of the materials he had used, but every precaution had been taken to prevent the introduction of impurities in the course of casting. He was also thinking of carrying out tests to study the intercrystalline occurrences in the gamma phase.

Professor Turner stated that no single test could give all the information required, and whatever the test was it should be criticised, but in the course of the discussion no other test had been mentioned apart from the Izod, which had been adopted by the author. The latter's contribution had opened out a wide field for investigation.

THERMAL COEFFICIENTS OF EXPANSION OF METALS.

The second paper read on Wednesday morning had reference to the "Determination of the Thermal Coefficients of Expansion of Some Commercial Metals and Alloys," by Dr. J. Newton Friend and Mr. R. H. Vallance. The paper was read in abstract by the latter, and we reproduce it, in abstract also, on page 352 of the present issue.

Mr. D. Lewis said he was interested in the actual measurement of small changes occurring in metals and alloys, and referred to an electric device which came into play when even the smallest roughening of a polished surface was encountered. The device was connected to a telephone, but a disadvantage had been that the change of note in the ringing could not be recorded. Since then the device had been perfected, and it now gave an autographic record. There was no mechanical friction to deal with, the measurements were entirely electrical and the instrument was a most sensitive one.

Professor Turner found that the authors' results agreed generally with the values already accepted, which suggested that their apparatus worked satisfactorily.

THE MECHANISM OF FATIGUE FAILURES.

The first paper taken at the afternoon meeting on Wednesday was entitled "The Investigation of a Fatigue Failure of Brass Tubes in a Feed-water Heater, with a consideration of the Nature of Fatigue." It had as its authors Mr. W. E. W. Millington, M.Inst.C.E., and Professor F. C. Thompson. In it was described a failure of brass tubes due to vibration set up by a current of steam, and also an attempt was made to picture a mechanism capable of reproducing results in accord with actual observation on fatigue failures. The authors assumed that the atoms of the alloy could be regarded as a pile of spheres. Of such

piles two systems of closest packing were possible, namely, the face-centred cubic and the hexagonal. The crystal of the alloy being of the face-centred cubic type, the authors pointed out that layers in the corresponding pile of spheres could be shifted over each other by an "easy glide" for a certain distance, but that a larger displacement called into play higher resistances. It was in overcoming these that they maintained that slip bands arose. They further stated that if a permanent deformation was produced within the limits of the "easy glide" a greater force would be required to reverse the displacement than had been needed to produce it. A full summary of the paper will be found on page 353.

The discussion was opened by Professor C. T. Jenkin, who congratulated the authors on a most interesting and suggestive paper.

The explanation given as to why a larger force was required to reverse a displacement than to produce it made it possible to visualise the production of fatigue. One great difficulty in explaining fatigue failures had been the large number of reversals of stress required for fracture, but the author's theory provided an easy method of visualising how this happened. On the first production of a strain, a few layers would slip by "easy glide," but owing to the small number of molecules affected, no effect would be visible on the surface. On reversing the stress, the slip was not reversed, but "easy gliding" occurred in some other plane. At each cycle only a few molecules were effected, and hence millions of cycles were required to produce any visible effect. This was a new method of accounting for the long time required to produce failure by fatigue. He thought however, from some of his own experiments that the viscosity of the metal might also be involved.

The next speaker was Miss Elam, who held that it was going too far to represent the atoms of a metal by spheres rolling over each other. The "easy glides," which the authors assumed must lead to hexagonal arrangements of the atoms on some planes, and of this there was no evidence, as it had not been proved that this type of structure was produced by work on a metal. Moreover, it was well known that in tensile tests the first displacement occurred along planes making an angle of 45 degrees with the stress, and not along planes of minimum area, as the authors' theory suggested, and it was contrary to observation to assert that a displacement started along one plane ceased to proceed in that plane unless the direction of the stress was altered.

Mr. Gough, who followed, said that there had been many theories of fatigue failures, each based upon a limited number of observations. Perhaps in time we should get a complete theory, made up of elements taken from all these different provisional hypotheses. The new theory advanced by the authors, did give an explanation of some difficulties. Referring to the statement in the paper that the tubes had failed under a calculated stress of 60 lb., the speaker said that, of course, when vibration occurred this nominal figure was meaningless. There had been much trouble with failures due to the vibration of aeroplane wire stays, which had been overcome by putting in a knuckle joint at the bottom end. The real breaking stress in the broken wires was not the calculated statical stress. The authors had quoted Professor Carpenter to the effect that slip occurred on the octahedral planes. In some experiments by Mr. Hanson and himself slip bands were found on other planes and at very low stresses. It was quite possible, however, that the actual slip did occur on the octahedral planes, but that the average plane of slip might be elsewhere. The authors' seemed to assume that a material had a definite fatigue range, which was found by plotting endurance against the limiting stress. In the case of steel the curve thus obtained ultimately became horizontal. With aluminium, however, a curious stepped curve, with nearly horizontal sections, followed by sudden breaks was obtained, and with copper there was no fatigue range at all. Taking steel, however, it had been shown that if a specimen was submitted to some millions of repetitions of alternating stress somewhat less than the fatigue limit, it could then be subjected to a higher range of alternating stress than it would have been able to carry without the preliminary treatment. He believed this was due to the fact that if the high load were imposed at the outset the strain was concentrated on small areas, and was so great that the specimen broke. By subjecting it to many reversals below the fatigue limit wide areas of bands of small slip were produced, with the result of equalising the stress on the crystal.

Dr. W. Rosenhain said that every contribution to the study of fatigue was of interest, but he could have wished that the paper had displayed more regard to the fuller knowledge we now possessed as to the nature of atoms and molecules. As it stood, he thought that the paper explained nothing, and that the experiments with the piles of spheres were misleading. Atoms certainly did not behave like solid spheres. The authors appeared to ignore the layers of spheres above the layer in which they assumed the "easy glide" to occur. As a matter of fact, however, this "easy glide" would involve the lifting of the whole superincumbent pile. He thought the authors had no justification for carrying their analogy so far, without further very definite experimental evidence. The theory was ingenious, but it failed to explain the whole phenomena of fatigue. A single "easy glide" would mean a displacement of about 3 Angström units, and this would produce no visible effect at the surface. If it occurred not at a single layer, but on every plane there would still be no visible slip, but a general distortion of the crystal. Experiment showed, however, that a strain beyond the elastic limit produced localised slip, and the intervening metal between the slip bands was apparently unaltered. Under alternating stress polished surfaces showed visible slip bands at stresses far below the fracture limit. Easy glide might produce mechanical twinning, but there was, he considered, no evidence that it had anything to do with fatigue which, according to the authors, arose from multiple twinning. Now there were metals, such as iron, in which fatigue failures were certainly not associated with twinning.

Mr. C. E. Stromeyer took exception to the authors' assertion that the failure described was due to fatigue. He had calculated that to produce a stress of 1,000 lb. per square inch, the bottom box would have had to move about 1 in., and he did not think that the metal of which the tubes were made ought to fail under a fatigue stress of less than 5,000 lb. per square inch, at any rate in so short a time. In the case of copper pipe failures, which he had studied many years ago, he had estimated the stresses as ranging from 5½ to 13 tons per square inch. He could not admit, therefore, that good brass tubes broke at such very low stresses as would be involved had the failure been due to fatigue. He would suggest the presence of some impurity. Steel was a very tough material, yet mysterious failures did occur, which the speaker attributed to the presence of nitrogen. In brass it might be something else.

Dr. Hanson, who followed, said that he could not agree that the markings noted by the authors on the broken tubes were evidence of failure by fatigue. He had seen just such markings on metals which had never been subjected to fatigue, as, for example, in cold-drawn copper. The "bars" found might be due to turning, but they had nothing to do with fatigue. Slip bands were, he continued, produced well within the fatigue range, and he illustrated this by lantern slides, showing such bands, both on steel and copper. These accumulated as the repetitions of stress went on, and since millions of slip bands were produced before failure occurred, there was here an explanation of the time taken to produce failure by fatigue. to which Professor Jenkin had referred. It was not essential that the alternating stresses producing fatigue failures had zero as their mean value, but both limits might be above the zero stress line, and, in fact, failure might also occur under purely compressive stress.

Dr. Desch said that his chief difficulty in reading the author's paper had been to imagine atoms as hard spheres. As a matter of fact, an atom was a very empty structure. Nevertheless, there were many facts that could be co-ordinated by assuming definite atomic volumes, that it was quite possible that the authors might be able to translate their views into a different and more modern language, without altering the general character of their hypothesis. Nevertheless, there were certain difficulties. When slip occurred, it was not along adjacent planes, but in blocks separated from each other by thousands of atomic distances. Slip was, in fact, confined to a small fraction of the crystal grain, and so far no theory had accounted for this, which also held in fatigue fractures. A partial explanation had been given by Beilby with his theory of a breakdown of atomic structure. The speaker had found bars such as described by the authors, in severely stressed β brass. The specimens were put aside for three years, and then repolished and etched. It was then found that this structure had disappeared, so that such displacements did heal themselves up in time.

The discussion was concluded by Mr. Turner, who said that the authors' hypothesis had given him a clearer view of the nature of slip and twinning than he had previously possessed. In comparative fatigue tests on hollow and solid specimens it was found that the former broke 70 times more rapidly than would have been expected, and he thought an explanation of this might be based on the theory set forth in the paper.

In reply, Professor Thompson said that they had dealt in this paper simply and solely with "close packed" material, such as copper and brass, and not with iron and steel. Under mechanical deformation copper and brass did not behave like steel, and this fact discounted much of the discussion. They had dealt, in short, with one particular space lattice which was not that characteristic of iron. The paper indicated clearly that there was no relationship between the elastic limit and the fatigue limit. This, of course, was not novel, but if from their speculations this result could be deduced, it was a point in favour of their hypothesis. Assuming the atom to be represented by a ball, they were able to explain twinning, and to show why α iron would twin, whilst γ iron would not. Some of the observations made on twinning were incapable of explanation, if the twinning were primary, but the difficulty disappeared if secondary twinning occurred, as the authors had suggested. As a first approximation, they believed they were. justified in assuming that the atoms in a crystal behaved like a pile of ping-pong balls. Indeed, it appeared to be a very close approximation to the truth, and there were no experiments in conflict with this view, though it was possible that the authors were in error in ascribing fatigue to the formation of these bands, but this was a deduction and not an essential part of their theory. He might add that they had been able to extend it to other space lattices, and this was described in a paper accepted by the Iron and Steel Institute.

Strength of Aluminium at High Temperatures.

The second paper taken at the meeting on Wednesday, dealt with "The Tensile Properties of Aluminium at High Temperatures." It was contributed by Mr. T. Martin, who read it in abstract. It stated that tensile tests in two qualities of aluminium at temperatures up to the neighbourhood of the melting point showed a continuous diminution in the strength of the metal, with corresponding increase of ductility up to about 325 deg. C. At this temperature a marked change in the mechanical properties, shown by disconuities in the maximum stress and other curves, took place, which was attributed to a sudden increase in the rate of recrystallisation of the metal. Tests on cold-worked material indicated that up to 200 deg. C. the added strength conferred by cold work was well maintained. Above this temperature the rate of softening was such that tests to have any practical value must be made on metal previously fully annealed. The results brought out the importance of quantitative observations of the time and temperature conditions of annealing as a preliminary to tensile testing at high temperatures. Tests on the less pure metal showed that the effect of the impurities present was to make the metal stronger but less ductile at all temperatures, whilst a marked increase in ductility occurred at a temperature fully 75 deg. C. higher. Tests at two different rates of extension showed that at all temperatures above the atmospheric, the maximum stresses observed for the faster rate were greater than those for the slower rate, the effect increasing with the temperature.

At 300 deg. C. a temperature at which aluminium vessels were frequently used in practice, the maximum stress observed might be increased by more than 10 per cent. by trebling the rate of extension. The results indicated that the time factor in high temperature testing was of greater importance than had been hitherto suspected. They raised doubts as to the value of hot tensile tests on metals as ordinarily carried out, and showed that in testing aluminium above room temperatures special methods must be used.

The discussion was opened by Mr. D. H. Ingall, who suggested that if the author made further tests with a smaller range between the temperatures chosen, he would get some interesting results, particularly in the neighbourhood of 200 deg. C. For his own part he believed that at high temperatures the metal was a mixture of viscous and crystalline substances, and that the peculiarities found were to be attributed to this constitution.

Dr. Seligman said that, over 20 years ago it had been noticed that in prolonged tests aluminium wires would break at the end of three weeks under two-thirds the breaking load as ordinarily determined. This matter of the time effect was of supreme importance, and it was highly desirable that further experiments should be made.

In reply, the author agreed that further tests were needed. He thought Mr. Ingall's suggestion that metal at high temperatures consisted of a mixture of viscous and crystalline material was insufficient to account for the phenomena observed, and he was, himself, convinced that the effects were due to a differential compromise between recrystallisation and annealing.

The Tensile Strength and Conductivity of Pure Copper.

A paper by Mr. W. E. Alkins on "The Relation Between the Tensile Strength and the Electrical Resistivity of Pure Copper" was next on the list. In the absence of the author it was taken as read. An abstract appears on page 347. There was no discussion.

Low-Tin Bronze Characteristics.

The last paper taken at Wednesday's meeting was entitled "The Effect of Cold-Drawing and Annealing on some Electro-Chemical Properties of a Low-Tin Bronze," contributed by Mr. Stuart H. J. Wilson; in the absence of the author it was introduced by Prof. Thompson. The paper showed that the thermo-electric power of a series of cold-drawn bronze wires had been determined. This at first rose, then ceased to do so, as the amount of cold work was increased. With still more work the thermo-electric power again increased. The curves showing the relationship of the thermo-electric power to the amount of reduction in drawing were analogous to those obtained for other physical and mechanical properties. The effect of the drawing operation at different depths in the wire was also investigated, and it was ascertained that the wire was very far from homogeneous. On annealing a cold-drawn wire the thermo-electric power at first underwent a little alteration, but at a temperature of 400 to 500 deg. C. it showed a rapid and important increase, thereafter falling to a value lower than that in the cold-drawn condition. Measurements of the electro-chemical potential showed at first a marked rise to a maximum, as the wire became more and more worked, then a fall to a minimum and finally again a rise.

There was no discussion, and when Prof. Thompson concluded, the meeting was adjourned to the following day. The Annual Dinner of the Institute was held at the Trocadero Restaurant on Wednesday evening.

(To be continued.)

THE LATE MR. IAN A. MCDONNELL.—We note with regret the death last Tuesday at Kilmacanogue, Bray, Ireland, of Mr. Ian Alaster McDonnell, of the East Indian Railway. Mr. McDonnell was 56. He received his scientific training at Trinity College, Dublin, and graduated B.A.I. His pupilage was served with Mr. J. A. F. Aspinall, and for two years after he continued as an assistant. He went out to India in 1895 as an assistant district locomotive superintendent on the East Indian Railway, and was promoted to the charge of the Dinapore district three years later.

INDUSTRIAL NOTES.

IN their demand for the amendment of the wages agreement the miners, as will be remembered, put forward the three following claims:—(1) The raising of the minimum wage from 20 per cent. to 40 per cent. above the wage of 1914. (2) The alteration of the ratio of division of income between wages and profits. (3) The provision in the monthly statements of more complete information on the costs of production other than wages. A joint meeting of the owners' and men's representatives was held in London on the 6th inst., as announced in our last issue, when Mr. Evan Williams, speaking on behalf of the owners, said they were prepared to make concessions both as to the amount of the minimum wage and the alteration in the ratio of wages to profits; facility would also be granted to the men's representatives to check the wage returns from the colliery books. Mr. H. Smith, president of the Miners' Federation, raised the matter of Lord Gainford's statement given on page 301 *ante*; Lord Gainford remarked that his statement was the expression of a private opinion, and he completely withdrew it on the explanation given of the facts. At a meeting on the 7th inst. it was agreed that the discussion should be continued by a committee formed of seven representatives from each side, to facilitate the examination of the problems involved. The committee immediately commenced sitting, under the presidency of Mr. Evan Williams, and has continued its deliberations day by day. The situation is complicated by differences in the claims made in different mining districts, notably in the South Wales coalfields. The South Wales miners demand a percentage increase equal to the increased cost of living upon present wage standards; an extra turn per week, to be spread over each shift for day-wage men and extra rate per ton or yard for piece workers; a guaranteed week of six days or six days' pay; two weeks' holiday per year with pay; all workers to be members of the Federation.

In the course of an address at Mansfield last Sunday, on the subject of miners' wages, Mr. F. B. Varley, M.P., said that if the coal owners would offer a shilling a day now and another shilling in July, he would say, "settle at once." They must have a national agreement which would give the workmen in all districts a subsistence wage, but it was not an easy task to get it. If they had only to consider the Eastern area, of which Notts formed a part, they could settle immediately, but they could not forget that they belonged to the Federation. The coalowners had made an offer which they had not been prepared to make in the early stages of the negotiations. They had gone further than they generally went in the early stages of bargaining. It must not be thought, however, that the 40 per cent. advance had been settled.

Representatives of the Federation of Master Cotton Spinners and of the Cardroom Amalgamation, met together on the 6th inst. to consider the difficulty which arose at the Thornham mills, Royton, but failed to reach a settlement, and the meeting was adjourned until Monday, the 10th inst. On the latter date, after a discussion lasting about two hours, the representatives of the Cardroom Amalgamation left the meeting and stated later that they could not agree to the terms proposed by the employers. The Amalgamation representatives added that they adhered to what they had put forward in the first instance, namely, that the disputed points which arose between the Thornham mills and the two women feeders should have been adjudicated under a neutral chairman. They had therefore withdrawn from the Thornham dispute, and left the matter to be settled between the management and the two women concerned. The two women have now returned to work and the lock-out notices have been withdrawn.

The National Union of Railwaymen have approached the railway companies with the request to consolidate in the weekly wages the balance of 16*s.* 6*d.* in the war bonus of railway shopmen, and to grant these men one week holiday with pay. The shopmen's war bonus of 26*s.* 6*d.* per week had gradually been reduced to 16*s.* 6*d.* in the case of a large majority of the men; in some cases the bonus had been reduced to 10*s.* About a year ago the railway companies notified the unions of their intention to reduce the 16*s.* 6*d.* bonus by 6*s.* 6*d.*, bringing it down to 10*s.*, the figure paid to men in the engineering trades outside the railway shops. The request by the National Union of Railwaymen will probably be negotiated direct between the union and the companies.

A report is current to the effect that members belonging to a number of unions covering the shipbuilding and ship repairing industries, have sent in claims for an increase in wages to the Employers' Association of the Port of Liverpool and the Mersey Ship Repairers' Federation. The Federation of Engineering and Shipbuilding Trades is claiming an advance of 1*l.* per week; the National Amalgamated Union of Labour an advance of 12*s.* 6*d.* per week; the Amalgamated Engineering Union an advance of 10*s.* per week; the Boilermakers' Society an advance of 1*l.* per week, and the Electrical Trades Union one of 10*s.* per week.

The Southampton shipyard engineers continue to maintain their claim to a 17*s.* 6*d.* advance in wages and are remaining on strike. The Federation of Engineering and Shipbuilding Trades has, so far, been unsuccessful in its efforts to deal with the situation. The delegates who visited the district on Monday last suffered a rebuff and returned to London. The strikers sent representatives to the Executive meeting in London to justify their action and to emphasise their views. A further effort is now being made by the Federation to arrive at a proposal acceptable to all parties. The situation is a very troublesome one, as it threatens the very existence of the Federation as negotiator on behalf of the members of the Unions.

Carmen and motor men to the number of about 500 employed at the St. Pancras goods station of the London Midland and Scottish Railway came out on strike last Monday; the carmen demand the reinstatement of vanguards and the motor men ask that trailers behind delivery motors be dispensed with. The National Union of Railwaymen consider the strike an unofficial one, since the men, in striking, have taken independent action; some prominent members of the union appear, however, to hold a different view. The company has stated that it will not alter its policy in regard to vanguards, but is prepared to discuss the question of trailers if the men return to work. The strike has spread to other depots belonging to the company.

The quarterly report from October 1 to December 29, 1923, now issued by the Associated Blacksmiths' and Ironworkers' Society, refers to the application for an advance of 10*s.* per week in wages made by the shipyard workmen, and states that compared with 1914 the increase received by craftsmen in shipyards on day work rates amounts to 18 per cent. and that of pieceworkers generally to 10 per cent. These advances are compared in the report with that of 45 per cent. in the engineering trade; 66 per cent. in coal mining; 100 per cent. in the building trades and over 100 per cent. in the railways. The membership of the society at the close of 1923 was 12,459, showing a reduction for the quarter of 490. The total income for the quarter, including 19,947*l.* from the Ministry of Labour and 1,732*l.* from the Board of Health, amounted to 27,216*l.* The contributions amounted to 4,034*l.* The total expenditure was returned at 38,781*l.*, including 20,255*l.* for State Unemployment and administration and 1,747*l.* for State Health Insurance and administration. The credit balance for the quarter, to September 29, was 22,490*l.* The society had repaid to their bankers the sum of 10,988*l.* (included in the total expenditure of 38,781*l.*) leaving a credit balance of 10,925*l.* on December 29.

The Swiss Federal Council, says *The Times*, has decided to stop on April 1 the grant of subsidies to relief work for the unemployed. It has also decided to put an end to the relief action on behalf of the partially unemployed, to the grant of subsidies to private industries, and to relieve employers from their obligations under the order for relief of unemployed. The Cantons will be entitled to maintain unemployment relief to partially unemployed, but only for a period which shall not exceed 120 days a year. The grant of subsidies by the Swiss Government to the private industrial firms of the country, coupled with the comparatively low prices for material quoted these firms by German manufacturers, is the reason why Swiss tenders for electrical machinery destined for British installations are under British tenders for similar machinery. Among the latest examples which have come to our notice are the following: For a 5,000 kw. turbo-alternator required by Keighley, a Swiss tender was 5,200*l.* below the lowest British tender, the estimated cost of the machine being about 20,000*l.* For extensions to the plant at the electricity stations at Fulham, for which the Metropolitan-Vickers Electrical Company, Limited, quoted 131,000*l.* and secured the order, a Swiss tender was submitted at 12,000*l.* less.

THE CABLE-LAYING SHIP CYRUS FIELD.—The cable-laying ship Cyrus Field, ordered by the Western Union Telegraph Company from the Société des Chantier et Ateliers de St. Nazaire, was launched at the Penhoet shipyard of the St. Nazaire firm on the 21st inst. The ship has a length of 64·30 m. (211 ft.), a breadth of 10·36 m. (34 ft.), and a draught of 4·87 m. (16 ft.). Her displacement is 2,155 tons and her carrying capacity 1,070 tons. She is equipped with 1,200 h.p. engines, designed to give her a speed of 11·5 knots on trial.

RELATION BETWEEN THE TENSILE STRENGTH AND THE ELECTRICAL RESISTIVITY OF COMMERCIALLY PURE COPPER.*

By W. E. ALKINS, M.Sc., Member (Oakamoor).

IT has been known for many years that the increase in the tensile strength which occurs to such a notable extent during the cold-drawing of copper is accompanied by an increase in the electrical resistivity, and this fact was responsible for the fixing of two standards, one for annealed and one for hard-drawn metal. In general, an increase of 2 per cent. over the resistivity of annealed copper was allowed for hard-drawn material, though this value was not universally adopted. The adoption of a single standard for all "hard-drawn" copper was clearly open to the objection that it did not take into account the precise amount of cold-working to which any particular sample of metal under test had been subjected; it was found in practice that the thinner the wire and the higher its tensile strength the greater became the difficulty of complying with the resistance specification. This has been recognized in several recent specifications, where a graduated increase in the resistivity with diminishing section and increasing tensile strength is allowed for.

It was in connection with the drawing up of a revised specification some little time ago that the author undertook a short series of experiments, with the object of investigating the connection between the increase in resistivity of hard-drawn commercially pure copper and its tensile strength; the results of these experiments are presented in the following notes.

The author is not aware of any published work on these lines.

The material used was copper of a fairly high degree of purity, taken from two reliable brands of imported wire-bars, denoted for convenience as A and B. Two series of determinations were carried out, one with metal from A and the other with metal from B. Each sample of metal was chosen when already in the form of hard-drawn wire, coils of very good quality being selected.

The sample from brand A was in the form of 100 lb. per mile hard-drawn wire (0·079 in. diam.), and easily complied with the G.P.O. specification in all respects. That from brand B was in the form of No. 4 S.W.G. hard wire (0·232 in. diam.). Analysis of representative samples of each gave:

TABLE I.

Element.	Brand A.	Brand B.
Copper	99·93	99·95
Lead	nil	nil
Iron	trace	trace
Oxygen (by difference)	0·07	0·05

A preliminary test of the homogeneity of the material was made by drawing down about 25 lb. of a second coil of A wire to 0·050 in. diam. Six pieces of approximately equal weight (about 4 lb. each) were cut, and the resistance of each was determined and reduced to terms of standard weight and temperature (40 lb. per mile and 60 deg. F.). The results are given in Table II:

TABLE II.

No. of Test-piece.	Resistance of 1 Mile at Standard Weight and 60 deg. F. (15·5 deg. C.).	Conductivity per Cent. to late G.P.O. Hard Standard.
	Ohms.	
1	21·750	100·09
2	21·741	100·13
3	21·753	100·08
4	21·754	100·07
5	21·742	100·12
6	21·754	100·07

(Tests carried out, as described later, on one-thirtieth mile lengths.)

These were regarded as affording satisfactory evidence of the homogeneity of the material from the point of view of its resistivity.

PREPARATION OF TEST WIRES.

(*a*) *First Series.*—Nine coils, each 2·5 lb. in weight, were cut and numbered consecutively from one end of the A coil; less than 25 lb. of metal was thus used in all. The first two coils were drawn to 0·050 in. diam. without annealing; one was kept and tested as thus drawn. Six of the remaining seven coils were drawn down, one to each of the following diameters: 0·072, 0·068, 0·064, 0·060, 0·056, 0·054 in.; the single outstanding coil, together with these six and the second coil which had been drawn to 0·050 in. diam., was annealed for an hour at about 600 deg. C.; they were then all quenched in cold water, thoroughly cleaned in dilute sulphuric acid, washed, and dried. The annealed 0·050 in. wire was tested in this condition. The remaining seven coils were drawn down to 0·050 in. diam. without any further annealing; thus nine samples, varying in hardness from fully softened (tensile strength, 16·5 tons per square inch) to very hard (tensile strength, 32·2 tons per square inch), were available.

(*b*) *Second Series.*—Eleven coils, each about 10 lb. in weight, were cut. The procedure was essentially the same as in the case of the first series, but the wires were all drawn to 0·112 in. diam (200 lb. per mile size); the diameters at which intermediate annealing was carried out were: 0·116, 0·120, 0·128, 0·136, 0·144, 0·160, 0·176, 0·192, and 0·212 in.

TESTING.

(*a*) *Resistance.*—The resistance determinations were made by means of a 5-dial resistance-box by Elliott Brothers, London, reading to 0·0001 ohm., a mirror galvanometer by Kelvin & White, Glasgow, being used. The distance from the mirror to the graduated scale was about 4 ft., and the deflection due to a variation of resistance of 0·0001 ohm was readily seen. The length of wire tested was nominally one-thirtieth of a mile (176 ft.); the actual length was never checked, the position of the terminals remaining unchanged during the whole of each series of determinations. The terminals of the drum were connected to the resistance-box by leads, and the resistance of the latter was checked between each two observations. The wire was run on the drum and left for ten minutes to attain the temperature of the latter: the temperature was read, within five seconds of the completion of the resistance measurement, on a Fahrenheit thermometer hanging behind and just clear of the drum. The wire was cut off inside the terminals, coiled, and weighed to the nearest one two-thousandths (0·0005) of a pound.

The observed resistance was then corrected to standard weight and temperature. The temperature coefficient used was that given by the British Engineering Standards Association: three observations of the coefficient gave values differing by less than one-tenth of 1 per cent. from this figure. Temperatures were read to one-tenth of a degree; in the case of the first series of determinations it was found possible to carry out the whole of the observations, while the temperature varied only from 58·3 deg. F. to 59·1 deg. F.; with the second series the variation was about 5 deg. F.

(*b*) *Tensile Strength.*—Tensile test-pieces cut from the middle of the resistance test-pieces after being weighed were broken under slow loading in a lever machine of 1,000 lb. capacity, reading to pounds. The values adopted were the means of five concordant determinations. The tensile strength was corrected to standard weight.

RESULTS.

The results are shown in the subjoined tables. In Fig. 1 the increase in resistivity (per cent.) over that of the annealed metal is plotted against the tensile strength.

TABLE III.—*First Series. Tested at 0·050 In. Diameter.*

No.	How obtained.	Tensile Strength. Tons per Sq. In.	Resistance of 1/30 Mile at 60 deg. F. and Standard Weight	Increase of Resistivity over Soft.
			Ohms.	Per cent.
1	Hard-drawn throughout	32·24	0·7192	3·32
2	Annealed at 0·050 in.	16·53	0·6961	—
3	,, ,, 0·054 in.	19·98	0·7052	1·31
4	,, ,, 0·056 in.	21·40	0·7063	1·47
5	,, ,, 0·060 in.	24·07	0·7099	1·98
6	,, ,, 0·064 in.	25·51	0·7108	2·11
7	,, ,, 0·068 in.	26·15	0·7130	2·43
8	,, ,, 0·072 in.	27·09	0·7136	2·51
9	,, ,, 0·079 in.	28·23	0·7147	2·67

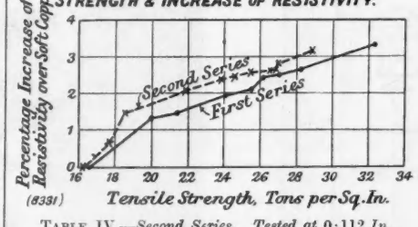

RELATIONSHIP OF TENSILE STRENGTH & INCREASE OF RESISTIVITY.
Percentage Increase of Resistivity over Soft Copper.
Second Series
First Series
Tensile Strength, Tons per Sq. In.
(8331)

TABLE IV.—*Second Series. Tested at 0·112 In. Diameter.*

No.	How obtained.	Tensile Strength Tons per Sq. In.	Resistance of 1/30 Mile at 60 deg. F. and Standard Weight.	Increase of Resistivity over Soft.
			Ohms.	Per cent.
1	Hard-drawn throughout	28·88	0·14368	3·14
2	Annealed at 0·112 in.	16·19	0·13930	—
3	,, ,, 0·116 in.	17·64	0·14021	0·66
4	,, ,, 0·120 in.	18·55	0·14132	1·47
5	,, ,, 0·128 in.	21·85	0·14219	2·08
6	,, ,, 0·136 in.	23·88	0·14259	2·38
7	,, ,, 0·144 in.	24·56	0·14271	2·47
8	,, ,, 0·160 in.	25·43	0·14285	2·56
9	,, ,, 0·176 in.	26·57	0·14297	2·65
10	,, ,, 0·192 in.	26·86	0·14298	2·66
11	,, ,, 0·212 in.	26·97	0·14318	2·80

The results of the second series of experiments are probably less accurate than those of the first series, for the following reasons: (*a*) The much greater weights of metal which was used renders it probable that the homogeneity of the material was less trustworthy; (*b*) the much greater variation of temperature which occurred during the resistance determinations of the second series renders them liable to greater errors in correcting for temperature; and, finally, (*c*) the actual value of the resistance to be measured in the second series was only one-fifth that in the first series: the error of observation—probably of the order of 0·0001 ohm—was therefore relatively five times as important as it was in the case of the first series. Hence, the series of determinations made with 40 lb. per mile wire is probably the more reliable.

A rather curious feature brought out by Fig. 1 is that the results for the second series are higher throughout than those for the first series; of this the author is unable to offer any satisfactory explanation. It was thought that it might be due to the insufficient annealing of the soft comparison wire of the first series, but further annealing of this wire at the original temperature and subsequently at a higher temperature, did not cause any further diminution of its resistivity.

For wires with a tensile strength of more than about 20 tons per sq. in.—and lower tensile strengths are seldom or never required—the increment of resistivity compared with the annealed metal is for all practical purposes a linear function of the tensile strength. For the electrical engineer, the specification of tensile strength for any given size of wire is usually a relatively easy matter. It is suggested that the maximum resistance allowed should be that of an annealed wire of the size required plus an allowance of a certain percentage, r, the value of r being numerically equal to one-tenth that of the tensile strength expressed in tons per sq. in. Thus, if T = tensile strength of any wire in tons per sq. in.:

$$r = \frac{T}{10} \text{ per cent.}$$

And if R_a and R_T represent respectively the resistance of an annealed wire of the same size and that of the given wire of tensile strength T, then:

$$R_T = R_a \cdot \frac{100 + \frac{T}{10}}{100}$$

$$\text{or } = R_a \left(1 + \frac{T}{1000}\right)$$

SUMMARY.

The relationship between the tensile strength and the increase in the resistivity of commercially pure copper in the form of wire has been investigated for two sizes of wire (40 lb. per mile; 200 lb. per mile). For tensile strengths above 20 tons per sq. in. the relationship is practically a rectilinear one, and it is suggested that in drawing up specifications for the resistance of hard-drawn wire of tensile strength T tons per sq. in. the maximum resistance allowed should be equal to that of an annealed wire of the same weight corresponding to the international standard, plus an allowance of one-tenth of T per cent. (*i.e.* $\frac{T}{10}$ per cent.).

* Paper read at the Meeting of the Institute of Metals on Wednesday, March 12.

TRACTION ACROSS ROUGH AND ROADLESS COUNTRY.*

By L. A. LEGROS, O.B.E., M.I.Mech.E.

(*Concluded from page* 319.)

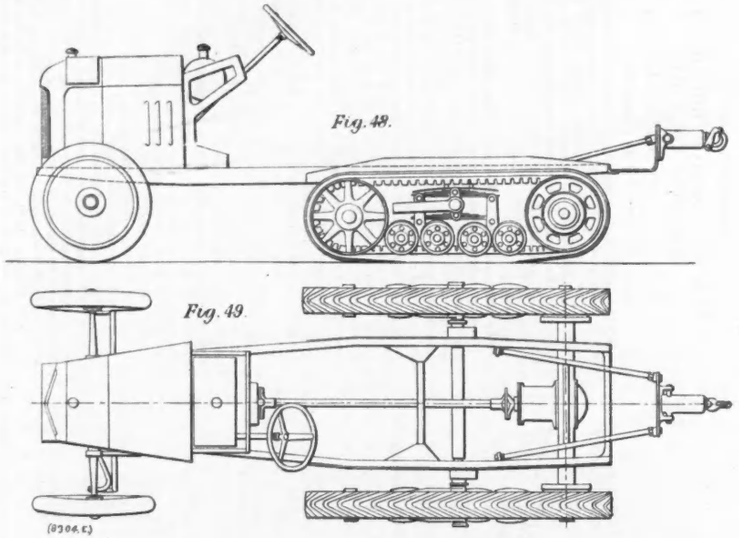
ON the three succeeding pages are given illustrations of various types of tractors. On the next page Figs. 48 to 51 show the Citroën-Kégresse chassis, with flexible track and details of suspension. Figs. 52, 53 and 57 show the Kégresse belt track for use on loose snow, Figs. 54, 55 and 56 illustrate the Kégresse front sledges for use on loose snow. Figs. 58 and 59 are perspective views of this car.

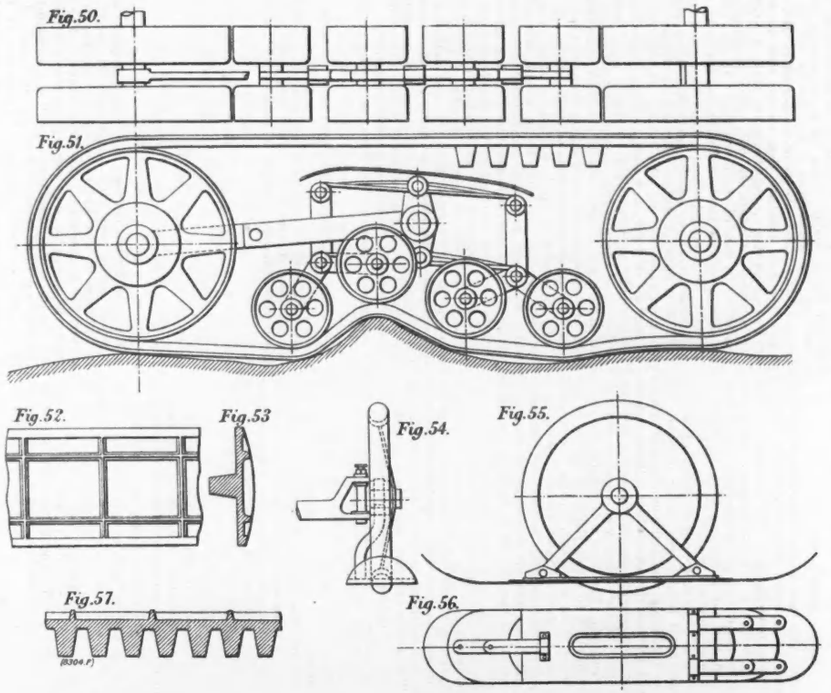
The Kégresse Car.—This car (Figs. 48 to 51) is fitted with a flexible belt track in some respects similar to the articulated chain-tracks of the American tractors, but differing from these in all details. Taking the Citroën chassis the back axle is detached from its springs which are removed; a second axle is arranged in front of the driving axle, and is fixed to the chassis; the track frame is carried in bearings on this fixed axle and is capable of tilting through angles of 35 deg up and 30 deg. down respectively. To the back axle on each hub a pair of pressed steel wheels are secured of which the cylindrical outer surfaces carry the belt and the inner surfaces are made slightly conical and adjustable, so that they grip the internal pyramidal projections of the belt-track. The front of the track frame is fitted with an extension gear for taking up slack in the belt track and carries a pair of idle wheels (similar to the driving wheels) which guide the belt. Four pairs of small wheels 8 to 10½ in. diam. bear on the belt, on each side of the internal projections, and carry the weight through an arrangement of double compensating levers and springs. Straps are fitted to limit the travel of the back (driving) axle in a downward direction to 35 deg. upward inclination of the track frame.

The belt-track which is the essential feature is constructed of rubber covered fabric of similar construction to the ordinary pneumatic cover, and is from 6 to 8½ in. wide. The outside is furnished with ribs projecting a half to three-quarters of an inch arranged in ladder form, or in chevrons up to 1 in. deep, according to the surface to be run across or the general work to be done. On meeting a stone or other obstacle the idler wheels rise over it and the belt adapts itself to the conditions, a successive transference of part of the load taking place as the small carrying wheels pass over the obstacle, but, owing to the

* Paper read before the British Section of the Société des Ingénieurs Civils de France on February 20, 1924.

TRACTION ACROSS ROUGH AND ROADLESS COUNTRY.





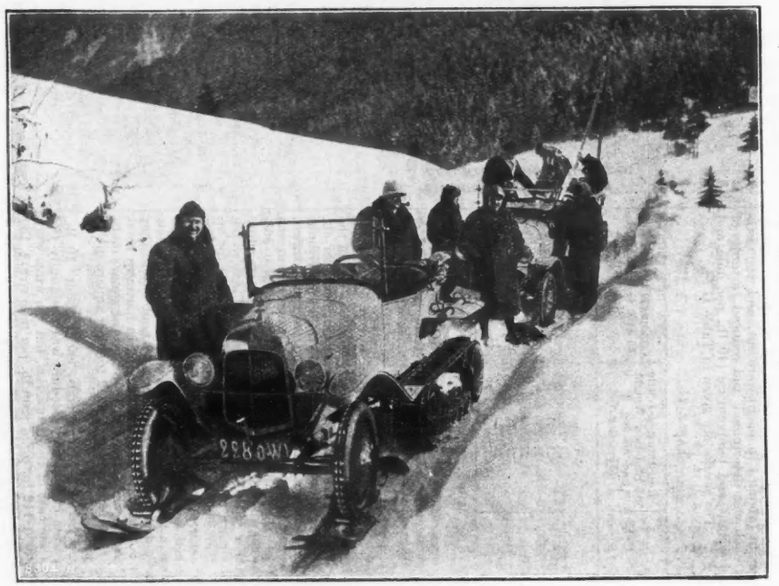


FIG. 58.

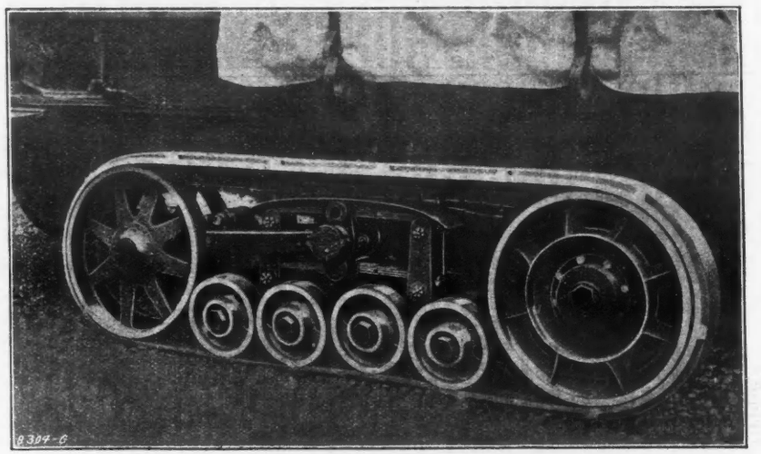


FIG. 59.

TRACTION ACROSS ROUGH AND ROADLESS COUNTRY.

FIG. 60

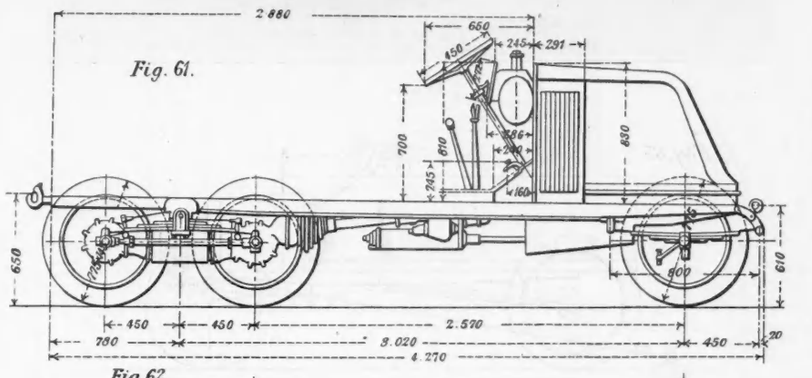


Fig. 61.

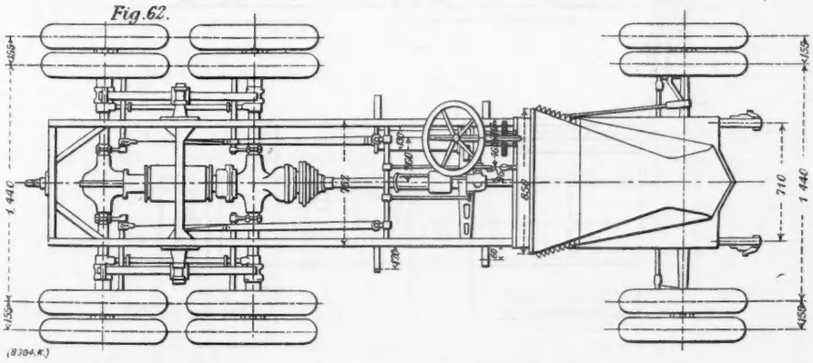


Fig. 62.

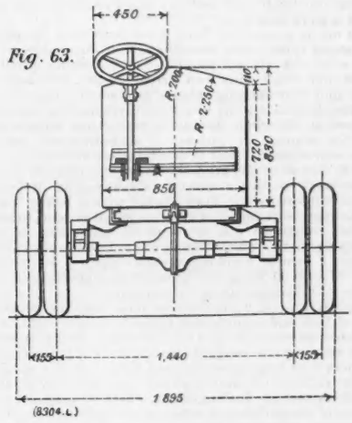


Fig. 63.

action of the compensating levers, no single pair of wheels carries much more than its due proportion of the load. The larger diameter of the front and back track wheels, 18 to 24 in., enables these to ride easily over larger obstacles. The insistent load on the tracks varies from 3·5 lb. per square inch light to 6 lb. per square inch loaded. This enables the vehicle to cross a snow field on which a man would require to use snow-shoes to avoid sinking. Figs. 52, 53, 57 and 59 show details of the track used for snow. When the car is on greasy clay or other material giving small adhesion, the differential can be locked.

Under ordinary working conditions the car is capable of climbing a gradient of 25 per cent. measured as the sine, but as it may be required to climb 70 per cent. (45 deg.) it has been necessary to fit a supplementary gear change and to strengthen the gear and back axle for the increased torque to be transmitted.

Steering is effected by the ordinary front wheels when running on roads, sand or moderately hard surfaces. For loose snow a sledge carried by arms pivoting on the stub axle is fitted, having a slot in the centre through which the tyre projects to a depth of about 2 in., which provides sufficient lateral resistance for steering shown in Figs. 54 to 56 and 58.

At present there are two types of chassis fitted with the Kégresse tracks. The smaller is the small Citroën (Figs. 48 and 49) capable of developing 17 h.p. and carrying a load of 1,500 lb.; and the larger is a Mors having an engine capable of developing 42 h.p. and carrying a load of 30 cwt. These cars when loaded carry nearly 80 per cent. of the weight on the tracks, and this figure may rise to 95 per cent. when running on low gear. The life of the belt track has not yet been determined because of the great variety of conditions, but the achievement of crossing the Sahara, 1,550 miles, was effected by the vehicles on one set of tracks, and it is reported that they appeared to be good for making the return journey, though actually to avoid any risk a fresh set was fitted. On the road a speed of 35 miles an hour can be attained. The car travels practically as smoothly as if on pneumatic tyres, and the life is stated to be as good as that of the ordinary tyre cover.

The crossing of the Sahara by automobile was first attempted in 1916 and attempts were repeated on many occasions, but the loose sand proved too great an obstacle. The first successful crossing was accomplished by the Haardt-Audouin Dubreuil expedition, a convoy of five Citroën-Kégresse cars, from Tuggurt to Timbuctoo, following approximately, the caravan route. This "raid" was carried out with great care, supplies being carried down from Tuggurt to In Salah, and as far North as Tin Zwaten from Burrum on the Niger. Thus about one-third (550 miles) of the worst part of the desert, flanking the Hoggar mountains, was left to be run across without picking up supplies. The expedition left Tuggurt at 5 a.m. on December 16, 1922, stopped two days at In Salah and also two days at Tamanrasset, arriving on the evening of January 4, 1923, at Burrum, where it stopped one day, and on the evening of January 6 reached Timbuctoo. The total running time from the railhead at Tuggurt to Burrum was 15½ days. Three of the cars carried 24 gallons of petrol, one carried 112 gallons and the other 224 gallons as a reserve against difficulties or need for exploration. Fig. 60 shows the Citroën-Kégresse cars in the desert.

Multi-wheel vehicles.—Trials had been made on the dunes of the Sahara that showed that wheeled vehicles, provided the wheel surface was sufficiently large, could be run over loose and moving sand. On the suggestion of General Estienne, Messrs. Renault constructed a six-wheeled vehicle, having front steering wheels and two back driving axles arranged as close together as practicable (Figs. 61 to 64). All the wheels are fitted with twin tyres of large section, but filled only to a low pressure. The particulars of these vehicles are as follows:—

The 6-wheel M.H. type Renault consists of the "10 h.p." (13·9 h.p. British rating) light lorry (nominal 15 cwt.) chassis with two rear axles arranged as close together as the tyres will permit. The pair of axles forms practically a non-swivelling bogie, arranged to give equal weight distribution on all the four wheels. The track, from centre to centre of the wheels, is 5 ft. 3in., and over the outsides of the twin tyres 6 ft. 3 in.; the wheelbase from the front to the forward back axle 8 ft. 5½ in., the wheelbase of the bogie is 2 ft. 11½ in; the overall wheelbase is 11 ft. 5 in.; and the length of the chassis overall is 14 ft. 2 in.

The total weight of the bare chassis, empty, is 1·2 tons. The motor is a "10 h.p." 4 cylinder, 75 mm. bore 120 mm. stroke; the gear-box has three forward speeds, the third being a direct drive, and one speed reverse. The propeller-shaft runs from the gear-box to a cardan joint arranged to give a large amount of play to the forward back axle; it passes through the casing of this axle above the centre and enters an intermediate gear-box on the forward back axle containing two sliding gears. The second shaft connecting the axles drives through cardan joints, the casing forming a jointed coupling between the two axles. Helical bevel wheels are used for axle drives. The driving axles are connected to each other by couplings with cardan joints and also to the back springs which are pivoted at their centres on the frame and act as compensating levers between the two axles. The springs are attached at the forward ends direct by pinjoints to the forward driving axle and at the rear ends by shackles to the rear driving axle. The tractive effort of the forward axle is transmitted to the frame through the springs, and that of the rear axle through the couplings to the forward axle and thence through the springs to the frame. The driving wheels are all fitted with internal-shoe brakes operated by wire-rope compensating gear. The tyres throughout are 775 mm. by 145 mm. of the "comfort" type.

Trials have shown that these cars can run practically anywhere in the Sahara on reasonable gradients, whether on shifting sand or on rough and rocky ground. These cars have recently crossed the Sahara by a different and easier route than that taken by the Citroën cars, from the North to Burrum.

The Gradis-Estienne convoy, of three Renault, type H.M., six-wheel cars, crossed the Sahara from Colomb-Béchar the South Western terminus of the Algerian railways to Burrum a distance of 1,900 km. (1,170 miles). It left Colomb-Béchar on January 25, 1924, at 0 hours and, taking a route to the westward of that taken by the Citroën convoy in 1922-23, arrived at Burrum on January 31 at about 11 p.m. Of the total 167 hours more than two days were lost owing to the direct route from Teccelit to Burrum proving impracticable for fast travel, necessitating a return to Teccelit and involving a distance of 400 km. in exploration; if the time taken for this is deducted from the total, the net time from railhead at Colomb-Béchar to Burrum on the Niger is reduced to 113 hours, a feat rendered possible by the good surface obtainable over a large section of the route recently explored by Lieut. Estienne between Touat and Teccelit. Fig. 64 shows the arrangement of the winch carried on these cars.

Overcoming difficulties.—Traction over rough country

involves knowledge of methods for getting cars out of difficulties. This has already been mentioned in connection with winches and scotches. It is possible to use a car to pull a greater load than its own weight and of this the Le Grain car used by the French during the war is a good example.

This car is a modified Ford fitted with twin tyres (or even triple tyres) with non-slip chains to enable it to cross soft and clayey ground. The steering gear is altered and fitted with two driver's seats, two sets of pedals and two steering wheels so that the driver can look ahead when driving in either direction. A winch is arranged at the front, driven by worm gear engageable with the engine. A means of anchoring the winch frame is provided so that it can be made fast to a balk-holdfast buried in the ground. By this means the winch can be used to haul a heavy vehicle out of difficulty without subjecting the Ford chassis to the heavy load; all that may be required of it is the small normal (nearly vertical) resistance due to want of alinement of the hauling rope; this means that a car weighing only 18 cwt. can pull a vehicle weighing several tons out of trouble. Figs. 65 and 66 show the general arrangement of the vehicle and its application in practice.

Conclusions.—In conclusion we have seen the development of four widely different types of tractor:—(*a*) The Armstead snow-motor of American construction appears to be an original method of solving the problem of transport over large snow-covered areas, but it is specialised for running on snow and ice. (*b*) The Pavesi articulated motor, of Italian origin offers a very original solution of the problem of arranging a vehicle to be proof against any distortion, caused by putting the axles in winding and capable of crossing sand and the roughest country. (*c*) The Kégresse tractor or lorry of French design and make which is an ingenious improvement on the articulated chain-track; a machine that can cross snow and ice, sand and marsh, rough country and run on the road, a machine that is as much at home on the snow of the Alps as on the sands of the Sahara, and has the distinction of being the first to cross the full width of the Sahara. (*d*) The multi-wheel vehicle, of which type the Renault is an example. This design, based on the suggestions of General Estienne was produced with the object of facilitating exploration and route-locating in the Sahara, and it has demonstrated its capacity for long-distance exploration.

Finally, the author desires to express his thanks to all those who have so kindly given him assistance:—to Col. T. M. Hutchinson for interesting historical matter, to the Institution of Mechanical Engineers, to Messrs. Knoblock and Armstead of the Armstead Snow Motor Company, to Signor Pavesi of Milan, to Messieurs Kégresse, Hinstin and Citroën, and finally to Monsieur Jannin of the Etablissements Renault.

THE BRITTLE RANGES IN BRASS AS SHOWN BY THE IZOD IMPACT TEST.*

By D. BUNTING, M.Sc., Student Member (Birmingham).

THE fact that a brittle range exists in brass at a temperature in the neighbourhood of 500 deg. C. has long been known to those engaged in the brass-casting industry. If a bar of 70:30 brass be heated to a suitable temperature, it may be fractured readily if struck a sharp blow with a hammer. An application of this property is made in practice when the workman breaks the risers off castings at a scarcely visible red heat. This property of brittleness is of considerable interest to those engaged in hot-rolling, hot-stamping, and similar work; and as certain brass articles, such as incandescent burner parts, are used at relatively high temperatures, it is important that it should be investigated.

The purpose of the research was to investigate the following: (1) The brittle ranges of brass varying in composition from 100 per cent. copper to 50 per cent. copper. (2) The effect of rapid cooling on the brittle ranges. (3) The cause of the brittle ranges.

The Brittle Ranges of Brass.—The only knowledge that was possessed with reference to brittleness in brass was, that it occurred in brasses of composition varying from 60 per cent. to 70 per cent. copper. It was not known if the brittle ranges extended far into the copper-rich α area or into the β area, and on this account it was proposed to perform a series of tests on alloys varying in composition from 99 per cent. copper to 52 per cent. copper, in order to determine the limits of the ranges, and also to compare the brittleness of the various alloys. In order to obtain a general indication of the character of the brittle ranges a preliminary test was first carried out. This consisted of heating a strip of brass to a selected temperature, and fracturing it by means of a hammer-blow; the angle of fracture gave an indication of brittleness.

Determination of the Limits of the Brittle Ranges.—As this preliminary test gave no quantitative value for the brittleness, some alternative method of testing had to be devised which would give accurate and comparative results. The test which appeared to be the most promising was the Izod impact test, which is somewhat similar to the method employed in the preliminary investigation.

The Izod machine used was a 23 ft.-lb. model, which possessed two auxiliary hammers, giving a range of 11, 23, or 46 ft.-lb. It was necessary, however, to carry out some of the tests on a 120 ft.-lb. machine, owing to the extreme toughness of certain alloys at atmospheric temperature. The test-piece used with this machine was the standard 120 ft.-lb. specimen. This was used in place of the smaller size (the 23 ft.-lb. test-piece), on account of the very low values obtained at high temperatures. The cross-sectional area of this test-piece is 10 mm. by 10 mm.; the length 75 mm.; the notch 28 mm. from the end, the radius at the bottom of the notch being 0·25 mm. Difficulty in testing at high temperatures was anticipated on account of the small clearance between the anvil block and the hammer. On this account it was impossible to surround the specimen with an electric furnace while testing. The simplest method that was suggested to the author of performing a test at high temperatures in this machine was to heat the specimen in a furnace separate from the machine, and to obviate the loss of heat consequent on placing in the cold vice, by securing the test-piece in metal clamps, which were heated together with the test-piece, and so maintained the temperature required while the test was being performed. These clamps, which were made of nichrome, measured 2½ in. × 1 in. × ⅜ in., and were slotted to permit of the insertion of a test-piece. Two countersunk screws secured the clamps, and enabled the test-piece to be gripped firmly. The anvil of the machine as supplied would not take this clamp on account of the narrowness of the aperture. To overcome this, two slots were milled in the anvil block, and the jaws of the vice were cut down in order to accommodate the clamp.

The test-piece was machined from a chill-cast strip ingot, measuring 12 in. × 4 in. × ½ in. Two strips were poured from each charge, and one strip was annealed in a muffle at 700 deg. C. for four hours. The annealed strip represented the brass in equilibrium, whereas the chill-cast strip was tested in order to discover the effect of abnormal conditions due to rapid cooling. The ingot was cut up into strips 4 in. × ½ in. × ½ in., which were machined to size on a shaper. The test-piece was notched in a milling machine 28 mm. from each end, and cut through the centre, forming two test-pieces. Only one test could be performed on each specimen owing to heat treatment, due to the temperature attained during the previous test, affecting the behaviour of the alloy in later tests.

A test-piece was taken, and in the notch was placed a thermocouple, which was wired into position, care being taken to avoid short-circuiting. The test-piece was then secured in the clamps, and a small iron cap placed on that portion of the test-piece which projected from the clamp, in order to diminish heat loss during the interval of removing from the furnace and carrying out the test. The test-piece, clamps, &c., were heated in a gas muffle to a temperature 25 deg. C. in excess of that required. The whole was rapidly removed from the furnace and transferred to the anvil of the machine, the vice being screwed up meanwhile. The test-piece was allowed to cool till the desired temperature was reached, when the cap was removed and the trigger pulled, allowing the hammer to fall. The time elapsing between removal from the furnace to the fall of the hammer was from 15 seconds to 20 seconds, and at 700 deg. C. results could be obtained agreeing to 2 ft.-lb. A nickel-Constantan couple and a millivoltmeter were employed for temperature determinations and gave readings accurate

* Abstract of a paper read at the meeting of the Institute of Metals on Wednesday, March 12.

TRACTION ACROSS ROUGH AND ROADLESS COUNTRY.

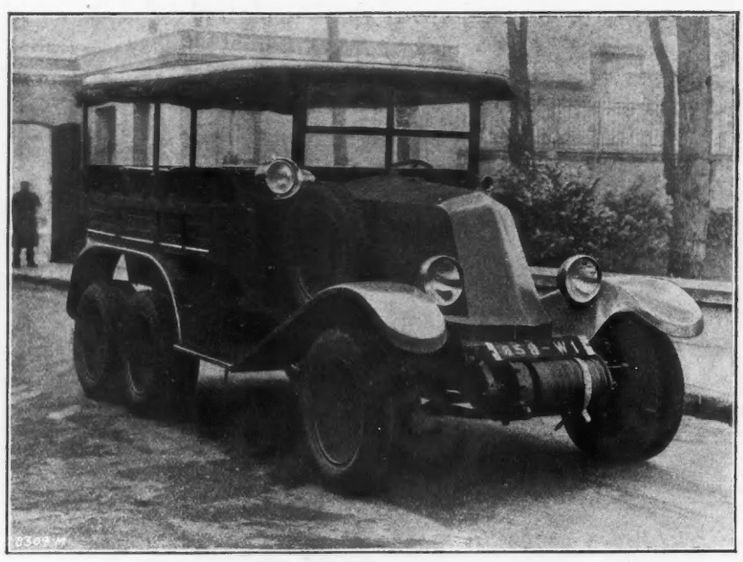


FIG. 64.

Fig. 65.

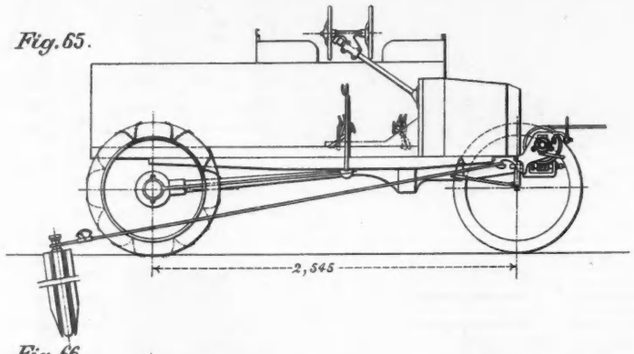
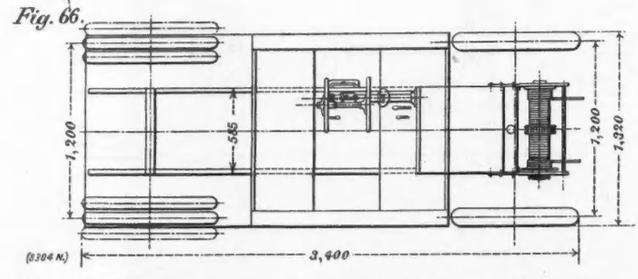


Fig. 66.



to 2·5 deg. C. Equal heating of the test-piece is not important in this test, provided that the temperature of the test-piece at the notch is obtained, as only that area of metal behind the notch is tested.

Impact tests were performed on a series of alloys, shown below, at temperatures rising by intervals of 50 deg. C. from room temperature to 700 deg. C. At certain points intervals of 25 deg. C. were taken, owing to rapid decrease in the impact figure.

Alloy.	Copper. Per Cent.	Constituents.
A	52·5	β
E	57·5	$\alpha + \beta$
X	60·8	,,
Z	63·9	α + a trace of β
U	65·7	α
W	70·1	,,
Y	75·2	,,
L	80·1	,,
T	87·5	,,
S	89·8	,,
N	99·0	,,

On examination of the Izod diagram (Fig. 2), it will be seen that the ranges exist in alloys varying in composition from 90 per cent. copper to 52 per cent. copper. When the percentage of copper falls below 51 per cent. the γ phase field is entered, and the alloy rapidly becomes brittle at atmospheric temperature. On account of the fact that the γ alloys are of no commercial importance, no tests were performed on brasses containing less than 52 per cent. copper. It was found that over the greater part of its area the brittle range possessed two limits: an upper limit and a lower limit. The lower limit of β (52·5 per cent.) occurs at 225 deg. C. This limit rises uniformly as the proportion of copper increases to 57·5 per cent., and from this point to 70 per cent. copper the limit is practically constant at 325 deg. C. At 70 per cent. copper the limit rises again until it occurs at 470 deg. C. in the case of the 90 per cent. alloy. Here the brittle range terminates, and so the lower limit, reversing its direction, and traversing towards the zinc-rich end of the diagram, becomes the upper limit.

The upper limit commences at a composition of 90 per cent. copper, the temperature of occurrence being

Fig. 1. THE IZOD TEMPERATURE CURVES OF ANNEALED BRASS

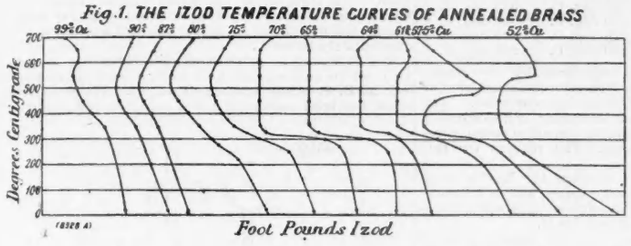


Fig. 4. THE IZOD TEMPERATURE CURVES OF CHILL CAST BRASS

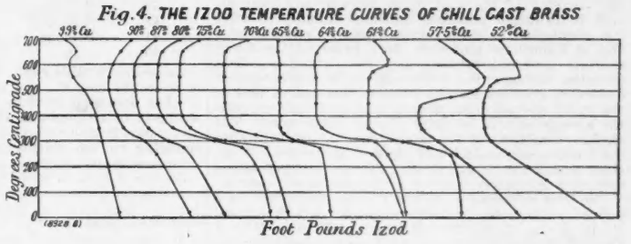


Fig. 2. THE BRITTLE RANGES OF ANNEALED BRASS

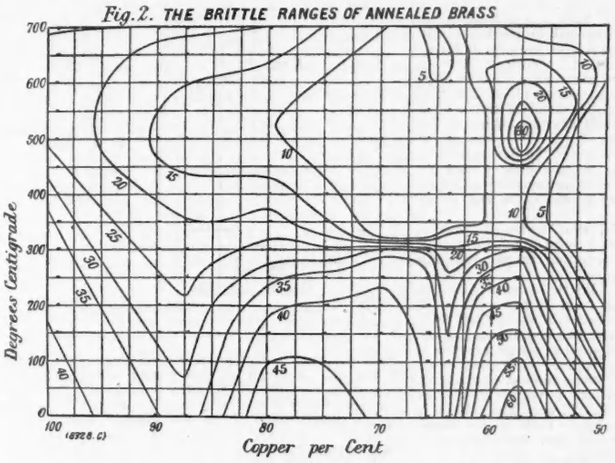


Fig. 5. THE BRITTLE RANGES OF CHILL CAST BRASS

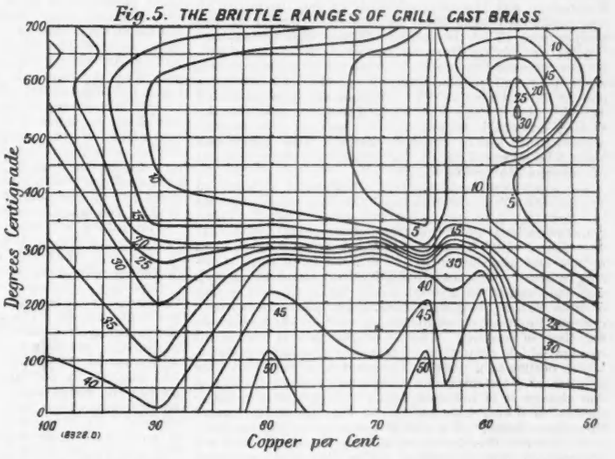


Fig. 3. THE BRITTLE RANGES OF ANNEALED BRASS

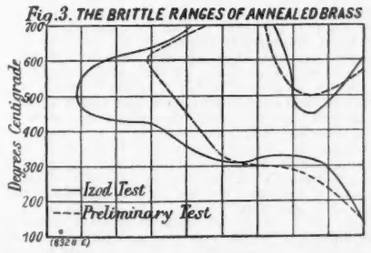
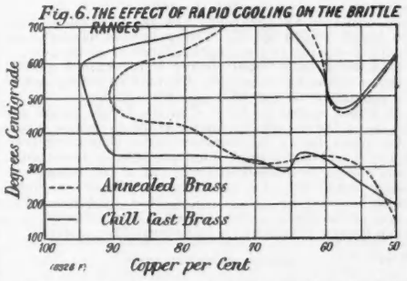


Fig. 6. THE EFFECT OF RAPID COOLING ON THE BRITTLE RANGES



On the completion of each test an Izod-temperature curve was plotted, showing the variation in brittleness of each alloy at various temperatures. These curves are shown in Fig. 1.

In order to furnish a means of comparing these results with those of the preliminary test, a brittle range diagram was constructed. This diagram was similar to the preliminary test diagram, with the exception of the manner of recording the result of each test. In this case a vertical component, in addition to the two horizontal components, was employed. This vertical component, which was the Izod figure, was registered as a spot height at the temperature of testing an alloy of a certain composition. When all tests had been filled in, contours were drawn at intervals of 5 ft.-lb., thus giving a representation of a solid model. This diagram is shown in Fig. 2. To compare this with the preliminary diagram some arbitrary standard of brittleness was required, and the author was of the opinion that the most suitable figure for this was 15 ft.-lb. On comparing these results with those obtained from the preliminary test, it will be seen that they are in close agreement, although the preliminary diagram is incorrect in one or two minor details, due to the relatively inaccurate methods of investigation. The results obtained from the two methods are compared in Fig. 3.

550 deg. C. Passing towards the zinc-rich end of the diagram, the upper limit rises uniformly to 700 deg. C. at 75 per cent. copper. From this point no upper limit was observed until the 61 per cent. alloy was examined, as the apparatus could not be employed above 700 deg. C. without softening of the blocks occurring. The upper limit appears again when the $\alpha + \beta$ phase field is entered, and occurs at 700 deg. C. at a composition of 61 per cent. copper. It now falls to a minimum of 450 deg. C. at 57·5 per cent. copper, and beyond this point the limit rises again to 550 deg. C. at 52·5 per cent. copper.

It would appear from the diagram that the recovery of toughness occurring in the $\alpha + \beta$ alloys at 500 deg. C. is only temporary, and that the alloy becomes brittle again at a temperature in the neighbourhood of 650 deg. C. This is not so, however. Below the circular area, denoting the recovery of toughness, the impact figure is below 15 ft.-lb., on account of brittleness. Above the area in question the impact figure falls below 15 ft.-lb., owing to the extreme plasticity of the metal at this temperature. This unfortunately cannot be shown in the diagram. The actual upper limit of the brittle range, taking this fact into consideration, is shown in Fig. 3.

The Effect of Rapid Cooling on the Brittle Ranges.—To determine the effect of rapid cooling on the brittle ranges, the foregoing experiment was repeated on a series of chill-cast alloys. The annealed alloys were regarded as in the normal state of equilibrium. The alloys examined were regarded as in the normal state of equilibrium. The alloys examined were exactly similar in composition to the annealed alloys, having been poured from the same charge. The Izod-temperature curves are shown in Fig. 4.

A diagram, similar to the brittle range diagram for annealed brass, was constructed showing the ranges of chill-cast brass (*see* Fig. 5). If this diagram is examined in comparison with the ranges of annealed brass, the variation due to rapid cooling can be observed. The ranges of the annealed and chill-cast brasses are compared in Fig. 6.

It will be seen that chilling has a pronounced effect on alloys varying in composition from 52 per cent. to 57·5 per cent. copper. No change is produced in the 52 per cent. alloy, but when the composition reaches 57 per cent. the limit is lowered 50 deg. C., and the impact figure at room temperature falls from 64 ft.-lb. to 45 ft.-lb. This is due to the fact that chilling produces an increase in the proportion of β, which causes the properties of the alloy to approximate more closely to those of the 52 per cent. alloy. From 60 per cent. to 70 per cent. copper chilling has no effect on the lower limit, with the exception of a sharp fall of 50 deg. C., which occurs between 63 per cent. and 65 per cent., *i.e.*, at the point where the α phase field is entered. This is evidently due to the final disappearance of β from the structural composition. Beyond 70 per cent. a marked lowering of the limit occurs. In the diagram of annealed brass the lower limit rises uniformly from 325 deg. C. at 70 per cent. to 470 deg. C. at 90 per cent. whereas the limit of chill-cast brass is constant at a temperature of approximately 340 deg. C. from 70 per cent. to 90 per cent. This change is due to coring.

The upper limit in the α area is affected in a similar manner to the lower limit, the influence of chilling being to raise the limit from 550 deg. C. at 90 per cent. to 670 deg. C. Thus chilling causes the brittle range to extend to a much greater depth into the area of the copper-rich α alloys. The area in which recovery of toughness occurs in the $\alpha + \beta$ alloys is practically unaffected by chilling, due to the fact that alteration in the relative proportions of α and β, caused by quenching does not influence the behaviour of the alloy on account of its approaching or entering the β phase field at the temperature of testing. It will be seen from the foregoing that the general effect of chilling is to cause an increase in the brittle ranges.

The Cause and Explanation of the Brittle Ranges.—On account of the crystalline appearance of the fractures, micro-examination of all fractured and cracked specimens was performed in order to determine the cause of brittleness, and whether it was due to a decrease in the intercrystalline cohesion. All the specimens obtained in the preliminary test were examined, the following method being employed: Copper was deposited electrolytically on the fractured surface to a depth of $\frac{1}{4}$ in., the fractured surface was then cut through and polished. Etching was performed by means of polish attack, and the specimen was examined under the microscope. It was discovered that all fractures occurring in the brittle range were intercrystalline. On the margin of the brittle range the fracture was in a condition which might be

termed the transition stage, the intercrystalline cohesion being equal to the intercrystalline cohesion of the crystal, and an intermediate type of fracture resulted. From this it was inferred that the brittle range was due to a decrease in the strength of the intercrystalline cement.

On this account several papers by Dr. Rosenhain and Ewen on the intercrystalline cohesion of metals and allied phenomena were examined. Dr. Rosenhain discovered that if certain pure metals were stressed in tension and then gradually heated, an intercrystalline failure would occur at a temperature just below the melting point. In a later experiment it was found that a similar result could be produced at a much lower temperature if the load were increased and allowed to act for a longer period. This is explained on the assumption that there exists between the crystals a layer of amorphous material which acts as a cement. This cement is produced during the solidification of the metal: two crystals are growing towards one another, and when practically touching, each crystal will endeavour to attract the still liquid molecules to within its own orientation. Owing to the continued fall in temperature, the viscosity of the still liquid portion will increase, until it no longer possesses sufficient mobility to enter the orientation of either crystal, and so remains as a film of amorphous material. In a paper on the X-ray analysis of cored crystals and solid solutions, Bain considers the amorphous material to be a space-lattice distortion gradient formed between two grains, and as the atoms are not in the normal relation to one another, the arrangement is in many respects amorphous. The strained condition of the interatomic balance will alter the various mechanical and physical properties. From these connections it will be seen that the intercrystalline cement is intimately connected with the brittle ranges.

The first reference to this brittleness was found in a paper by Carpenter and Edwards on "A New Critical Point in the Copper-Zinc Alloys at 470 deg. C." A thermal inversion occurring in brasses containing the β solution was investigated, and in the discussion it was mentioned that these brasses were brittle at the temperature of the inversion. It was also stated that brasses containing from 60 per cent. to 65 per cent. copper recovered their toughness above this temperature, while those alloys containing more than 65 per cent. copper did not do so. This phenomenon was explained as being due to the β solution breaking up into the $\alpha + \gamma$ eutectoid at 470 deg. C., and on this account a momentary loss of cohesion ensued. This hypothesis cannot be accepted, since later research has proved that no eutectoid inversion occurs.

The most recent work on this critical point is contained in a paper by Tsutomu Matsuda "On the Transformations in Bronze, Aluminium-Bronze, and Brass." These transformations were investigated in great detail. It was found that in all respects the transformation in bronze and aluminium-bronze differed from that occurring in brass. The transformation in brass at 470 deg. C. was observed to be a progressive change extending over a wide range of temperature; its progress being a definite function of temperature and not dependent on the time of heating. This is totally different from the change which occurs in bronze and aluminium-bronze, which occurs at a definite temperature if sufficient time is allowed. On account of the progressive nature of the change it is not reasonable to speak of the transformation point, but, rather, to use the term "transformation range," the critical point being the temperature at which the change terminates during heating and commences during cooling. The electrical resistance curve obtained showed a V-shaped form in the $\alpha + \beta$, β, and $\beta + \gamma$ areas. This curve would be linear if the eutectoid theory were correct.

A further paper was published by Hiroshi Imai, the conclusions drawn by Matsuda were confirmed, and further work accomplished. According to these workers, the transformation is not a change of phase, but a change of atomic energy; *i.e.*, not a change of atomic configuration, but rather a change of interatomic force in the space lattice.

According to this result the transformation at 470 deg. C. should be noted on the constitutional diagram by a dotted line instead of an unbroken line, to show that there is no phase change.

It has been proved that this brittleness is due to a failure of the intercrystalline cement. An additional proof of this is that, in the case of the 57 per cent. and 61 per cent. alloys, the fractures occurring in the brittle range passed through the boundaries of the large original β crystals, which are formed during the crystallisation interval, and not between the individual crystals of the $\alpha + \beta$ complex, in which the α separates out along the β cleavage planes, and so no distortion gradient will occur between the individual crystals. An instance in which the intercrystalline character of the brittleness has a pronounced influence occurs in the effect of chill-casting on the α brasses. Chilling causes a great increase in the brittle range of brasses varying in composition from 70 per cent. to 90 per cent copper, the effect being to lower the lower limit and raise the upper limit. This is due to the occurrence of coring. If the Izod temperature diagram for annealed brass (see Fig. 2) is examined, it will be seen that the brittle range from 70 per cent. to 90 per cent. copper is approximately conical in shape; the base of the cone at 70 per cent. extends from 300 deg. C. to 700 deg. C., and the apex occurs at 90 per cent. copper at 500 deg. C. When an 80 per cent. alloy is chill-cast, the composition of the crystals will vary on account of coring. The exterior of a crystal will be in the neighbourhood of 75 per cent. copper, while the interior will be correspondingly rich in copper. As the brittle range is an intercrystalline property, only the composition of the crystal exteriors will influence the brittleness, and on this account the brittle range of a cored 80 per cent. alloy will be that of the crystal exteriors, or that of approximately a 75 per cent. alloy in equilibrium. The result is that the lower limit will be lowered and the upper limit raised, thus increasing the range.

The intercrystalline cement is to all intents and purposes amorphous, and so a transformation which alters the interatomic cohesion in the space lattice will have a much greater effect on an amorphous cement which lacks the support given by the space lattice. For this reason an alloy will break with an intercrystalline fracture within this range, on account of the intercrystalline cement being affected to a greater degree than the crystal grain.

This β transformation explains the occurrence of the brittle ranges in $\alpha + \beta$, β, and $\beta + \gamma$ alloys, but does not do so in the case of the α alloys.

The temperature at which the transformation range of various alloys commences and terminates is given by Matsuda as follows:—

Per cent.		Commences	Terminates.
58	$\alpha + \beta$	350 deg. C.	500 deg. C.
53	β	325 deg. C.	500 deg. C.
50	$\beta + \gamma$	300 deg. C.	510 deg. C.
49	$\beta + \gamma$	300 deg. C.	500 deg. C.
41	$\beta + \gamma$	225 deg. C.	430 deg. C.
40	γ	260 deg. C.	285 deg. C.

According to this result a transformation also occurs in γ at 280 deg. C., and this transformation is similar to that occurring in β in that it is progressive. The writer is of the opinion that a similar transformation also occurs in zinc-rich α, the transformation range corresponding to the brittle range. The reasons for this inference are as follows:

In the $\alpha + \beta$, β, and $\beta + \gamma$ areas the brittle range coincides with the transformation range, and as a similar brittle range exists in the zinc-rich α some such transformation must occur to account for it.

A transformation similar to that occurring in β takes place in the pure γ alloys at 280 deg. C. over a very limited range (25 deg.). This transformation is indicated by a change in the physical properties, but is only detected by thermal analysis of very high sensibility. As this γ transformation, occurring over a very limited range, can only be observed with difficulty, the α transformation, which commences about 350 deg. C. and terminates in the neighbourhood of the solidus would not be detected by thermal analysis, owing to the magnitude of the range (600 deg.). The change of direction in the thermal curve would be inappreciable, and the upper limit would be in such close proximity to the solidus that no indication of its presence would be given; *i.e.*, the solidus arrest would mask the upper limit of the transformation.

The inference from this is, that a transformation range occurs in α brass similar to the A2 transformation in iron, and that this transformation range gradually decreases with increase of copper.

Summary of Results.—The brittle ranges exist in brasses of composition varying from 90 per cent. to 52 per cent. copper. The brittle range of the 52 per cent. alloy extends from 220 deg. C. to 540 deg. C., and as the percentage of copper increases, the range reaches a minimum at 57·5 per cent. copper, extending from 320 deg. C. to 450 deg. C. With further increase of copper the range extends upwards indefinitely, and at 65 per cent. exists from 325 deg. C. until the solidus is entered. At 75 per cent. an upper limit to the range is once more observed, the range now extending from 350 deg. C. to 725 deg. C. Beyond this point the lower limit (hitherto practically constant at 325 deg. C.) rises until, at 80 per cent., the range extends from 430 deg. C. to 630 deg. C. The range now narrows, and finally terminates in the neighbourhood of 90 per cent.

The influence of rapid cooling is to cause a general increase in the brittle ranges, due both to coring and to the production of increased quantities of β.

It would appear probable that the brittle ranges are due to a failure of the intercrystalline cement which takes place during the transformations that occur both in the α and the β solid solutions. These transformations affect the interatomic cohesion of the metal, and owing to the space-lattice distortion gradient or intercrystalline cement being unsupported by the bonding power of the space lattice, this effect is experienced to a much greater degree by the intercrystalline material.

DETERMINATION OF THE THERMAL CO-EFFICIENTS OF EXPANSION OF SOME COMMERCIAL METALS AND ALLOYS.*

By J. NEWTON FRIEND, D.Sc., Ph.D., F.I.C., Member, and R. H. VALLANCE, M.Sc. (Birmingham).

HAVING had occasion to determine the coefficients of expansion with rise of temperature for a considerable number of commercial metals and alloys, it was thought that a brief description of the apparatus used and of the results obtained might be of use, as the method is simple and rapid. The apparatus is shown in outline in Fig. 1, and consists of a steel tube, A, 27 in. in height and 3 in. in internal diameter. The lower end is screwed into a collar, which is bolted with four bolts on to a heavy steel or cast-iron base, measuring 12 × 12 in. and $\frac{1}{4}$ in. in thickness. This rests on four small studs in a heavy iron tray fitted with an exit tube M.

Four sets of four small studs project annularly at regular distances, D, E, F, G, within the tube to support copper discs (shown enlarged at the side in Fig. 1), 0·035 in. in thickness, and of diameter just sufficient to enable them to enter the tube and rest comfortably on the studs. The central holes, H, are of varying sizes, according to the diameter of the bars of metal to be tested, whilst the four small holes in the rim are only 0·25 in. in diameter, and allow the steam, entering at B, to pass freely through the tube and escape at C. Two small necks admit of the insertion of the thermometers T_1 and T_2.

The top of the tube is closed with a screw cap L, fitted with a neck into which a bung carrying a quartz tube N is fixed. The metal bar to be tested rests on a quartz cylinder Q, chosen because quartz has a negligible small coefficient of expansion. On the upper end of the bar rests a quartz rod which just slides through the quartz tube, the movement being facilitated by means of glycerine, the presence of which also prevents any steam escaping in this direction. The upper end of the quartz rod supports the base of an Ames dial gauge, the body of which is rigidly clamped to the upright steel bar SS, which is kept at a constant temperature by a water-cooled jacket, not shown in the figure. It is necessary that SS should be perfectly rigid. Its lower diameter is 1 in.; its upper, $\frac{3}{4}$ in.; and it is firmly secured to the base. The trough MM′ is kept at constant temperature by flowing water, and condensed steam, instead of collecting at the bottom of A, drains through a small tube R immediately below C.

On beginning an experiment, the metal bar is placed in position and a current of water passed in at C and out at B, R being temporarily closed. When a steady state has been reached the dial zero is noted, the water

Fig. 1.

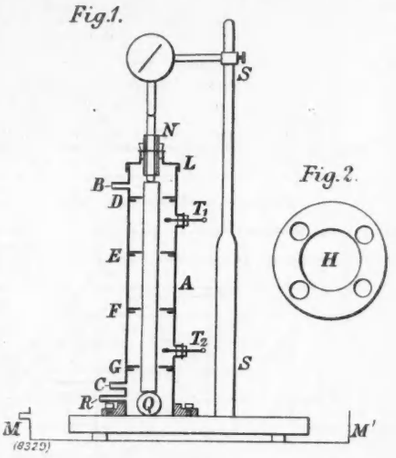


Fig. 2.

is disconnected and steam admitted at B. The reading of the dial is taken at this higher temperature, and from these data the coefficient of expansion is calculated.

The accuracy of the experiments is largely determined by the sensitiveness of the dial gauge. This is graded to 0·001 in., and the divisions can be estimated to one-fifth, so that if the dial is accurate the readings may be made to 0·0002 in. In an ordinary case, using 24-in. bars of metal, the expansion corresponds to 30 to 40 divisions, so that the manipulation error is appreciably less than 1 per cent. This is sufficiently accurate for most commercial practice, as the metals differ among themselves by fully this amount. A true test of the relative accuracy of the results would appear to be the ease with which "repeat" results can be obtained, and experiments show that this is all that can be desired, as duplicate determinations were made after intervals of two months.

During an experiment it was found that on first passing steam through the apparatus the dial hand moved gradually to a maximum, but on continuing the passage of the steam the dial reading diminished slightly and then remained steady. On cooling again with water, the hand moved back to a point behind zero, the difference in the two readings for expansion and contraction not always being the same. On readjusting the zero, however, and again passing steam, the dial moved to a maximum and remained steady, the expansion being numerically equal to the contraction in the first experiment, and, on cooling, the dial again returned to the new zero. This shifting of the zero, therefore, appears to be due to the bar accommodating itself to the apparatus.

The dial gauge was standardised by calibration with a spherometer. The authors tabulated the co-efficient of expansion of various metals presented to one of them by the manufacturing firms, and they represent their regular commercial products. The authors desire to tender their sincere thanks to the firms concerned.

* Abstract of a Note read at the meeting of the Institute of Metals on Wednesday, March 12.

BRITISH INDUSTRIES FAIR, BIRMINGHAM.—This British Industries Fair is to be held this year from May 12 to May 23 in the exhibition buildings, Castle Bromwich, Birmingham. The Council report that the demands for stand accommodation are greatly in excess of those for corresponding periods in former years. The period during which the fair is to be open this year being covered by the period the British Empire Exhibition at Wembley is open, it is expected that an additional number of overseas buyers will take advantage of this to visit the Birmingham display.

FATIGUE FAILURES OF BRASS TUBES.

*The Investigation of a Fatigue Failure of Brass Tubes in a Feed-Water Heater, with a Consideration of the Nature of "Fatigue."**

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THE apparatus in which the failure took place was a large water-heater of the tubular type arranged for taking water inside the tubes, the steam passing on the outside.

Fig. 1 shows a sectional elevation and Fig. 2 a sectional plan of the heater, which was of Messrs. Holden and Brooke's standard design of their "high velocity" type, arranged for the water to flow eight times through the steam space. The 192 tubes used were of solid drawn 70 : 30 brass annealed at the ends. They were 1½ in. diam. outside and 14 W.G. thick. At the top they were expanded into the water-box, and at the bottom into the floating head. The latter, as will be seen, hangs on the tubes, but otherwise is free to move, to obviate any stress due to unequal expansion. The steam passing through the heater was at a low pressure, at a temperature of about 140 deg. F. (60 deg. C.) on its way to a condenser.

When the heater was installed in the steam range, the water connections could not be made for a few weeks, and it was therefore filled up with water and put into operation, so far as the steam was concerned. After standing two weeks in this condition, the water in the tubes suddenly disappeared, and investigation showed that two of the tubes had broken on a plane at right angles to their length, and within a few inches of the top tube-plate. Obviously these tubes had broken well within the length at the end which had been annealed by the makers. Nothing could be done at the time except to lash up the broken tubes and prepare to replace them at the following week-end, it being assumed that somehow two faulty tubes had got into the batch. On opening up at the following week-end, it was found that three more tubes had failed similarly, and all five were replaced. A week later two more tubes were found to be broken, and it became obvious that this was no ordinary case of tube failure, and it also became imperative to diagnose the cause without delay.

The tubes were new. There was no evidence of corrosion, and the fracture was not of an intercrystalline nature, "season-cracking" being therefore excluded. Mercury cracking tests showed no signs of undue internal stress. The analysis of the brass was: Copper, 71·82 per cent.; zinc, 27·38 per cent.; iron, 0·31 per cent.; aluminium, 0·44 per cent.; lead and tin, trace. This also offered no explanation. When tested by bending and hammering the material was apparently quite ductile.

The surface of the fractures was that peculiar to fatigue failure having taken place on planes running through the crystals. There were in certain places some slight evidences of impurity at the crystal boundaries, but this was not sufficient to cause ordinary brittleness, as was clearly shown by the flattening tests.

Examination of the microstructure of the broken tubes near the fracture showed it to be absolutely normal, except for the presence of many straight lines in several of the crystals, which appeared to have all the characteristics of Neumann bands. Judging from these lines and the absence of evidence in any other direction, it was concluded that the failure must have been due to fatigue caused by vibration of the tubes in the steam space. It was not clear why the tubes should vibrate, but it was obvious that the remainder of the tubes would be in a more or less fatigued state, and it was, therefore, decided to cut out the whole of the tubes and replace them. The new tubes were supplied by the same makers, and were to all intents and purposes the same as the old ones, but in putting in the new ones two brass spacing plates (shown at S in Fig. 1) were put in the heater, arranged so as to divide the length of the tubes into three equal parts. In this way the tubes were considerably stiffened against vibration. As soon as this work had been carried out the heater was put into commission, and has now been working for some twelve months without the slightest sign of any further trouble.

Although one is, in view of the above, entitled to conclude that the failure was due to fatigue, it still remains to consider the exact nature of the process by which this occurred, especially as the calculated stresses imposed on the tubes under normal conditions were very low and only of the order of approximately 60 lb. per square inch tensile. It may be pointed out that the lines seen in the crystals show practically no sign of any faulting such as one would expect if slipping had taken place, nor do the twin and crystal boundaries suggest any marked plastic deformation. The natural conclusion to be drawn from these facts is that the stresses to which the tubes had been subjected never reached that limit at which normal permanent deformation occurs. The authors suggest, therefore, that the straight markings, the only abnormal feature in the structure, are the cause of the embrittlement which led to fracture. This point of view is more or less novel. In general, it has been considered up to the present that these markings are little more than the means by which fatigue may be diagnosed. In the new theory they become of profound importance in that they are the origin of the whole trouble.

In view of the great importance attached to the markings in the present theory, it is imperative that their nature and origin should be more closely considered.

* Abstract of a paper read at the meeting of the Institute of Metals, on Wednesday, March 12.

In the first place, the fact that they are bars as distinct from bands is beyond doubt. In every case where a section showing the effect was repolished and re-etched it was noted that the lines disappear, are replaced by others, decrease and increase in length, and generally behave in a manner which makes it quite certain that they are of bar formation. In fact, the only unchanging characteristic of the bars in any given crystal is their direction. Further, it is noted that in nearly all cases some bars appear parallel to the twin boundary in the crystal where this exists, and also at other angles which suggest agreement with the angles made by the intersection of the octahedral planes of the original crystal. It seems clear also that the bars have a rhombic cross-section, for they appear to be tapered, in some cases the double taper being clearly-seen, showing that the section plane crosses the centre line of the bar. When viewed under oblique light, it was quite clear that the bars were definitely crystalline, as on rotating the specimen on the microscope the bars became alternately light

Fig. 1.

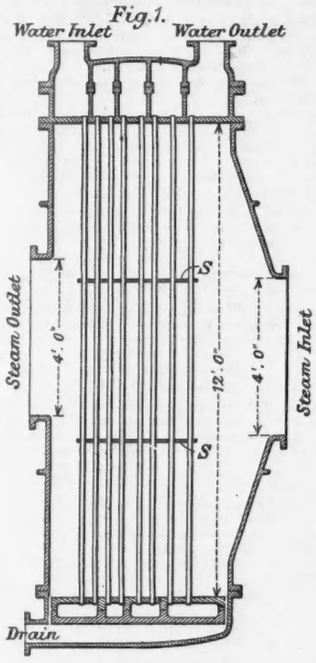
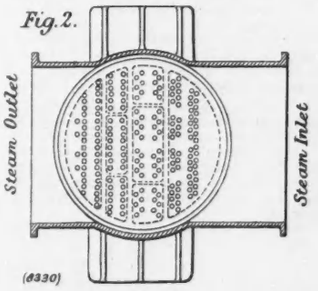


Fig. 2.



and dark, flashing up once on a complete rotation. The orientation of the bars was, however, quite different from that of the crystal in which they occurred.

Having thus demonstrated that the fatigue markings are bars of crystalline material of a different orientation from that of the crystal in which they were formed, it becomes necessary to explain their formation. To do this it is essential to study the crystal structure itself and the effect of stresses applied to it.

[The paper then discusses in detail mechanical deformation as revealed by X-ray observations.]

The two most important points which emerge from the discussion are, so far as the general nature of fatigue testing is concerned:—

1. That heat effects may be observed at stresses well below the fatigue limit. 2. That looping may occur in the stress-strain curve on reversal of the stress within the fatigue limit.

Incidentally, an explanation of the strengthening effect of the crystal boundary results from the resistance such boundaries offer to the gliding of planes of atoms. This is essentially the slip-interference theory of Jeffries and Archer of the effect of boundaries on the elastic limit.

Further, since glide can, as has been experimentally shown, occur in one crystal without the movement being transmitted into adjoining ones, it appears that a lower density of packing must, as one would naturally expect, be attributed to the atoms at boundaries compared with that of those within the mass of the crystal.

If the crystals were all rigidly interlocked, no movement involving permanent deformation could occur until a stress was reached at which the strongest crystal broke down, when entire fracture of the material would ensue, nor should we get twinning, which of necessity demands some flexibility at the boundary to permit of the re-orientation.

For the later consideration of fatigue failure, it is now highly important to consider how fracture actually takes place, especially as the authors' ideas on this subject are somewhat different from those hitherto generally accepted.

It is known that under ordinary conditions a crystalline metallic aggregate does not fracture at the crystal boundaries, but through the crystals themselves. We are faced with two reasons for this, either: (*a*) That the separation of the atoms of the different crystals at the crystal boundaries requires a greater effort than the separation of the atoms within the crystals themselves; or (*b*) that fracture takes place by some process within the crystals requiring a less effort than that for the direct separation of the atoms at the boundaries.

Apart from effects such as those due to surface forces, it is difficult to see what can occur to make the pulling apart of the atoms at the boundaries require a greater effort than the pulling apart of the atoms within the crystals themselves, where they exist in the most orderly arrangement. On the other hand, it is easy to see that if fracture takes place by the slipping of one layer of atoms over another, then this will inevitably take place within the crystals themselves, where the orderly arrangement of the atoms specially lends itself to such movement rather than at the irregular crystal boundaries where it is impossible to imagine slip taking place with any degree of facility. If this be so, then fracture might take place in the following ways, in order of increasing resistance: (1) Slip within the crystals; (2) pulling apart of the atoms at the crystal boundaries; (3) pulling apart of the atoms in the crystals themselves.

Apart from other evidence available, Carpenter and Elam have shown conclusively that, in the case of their single crystals of aluminium, fracture occurs by slip on octahedral planes, where the resistance to slip is less than the resistance to the direct separation of the atoms. If the direct separation of the atoms at crystal boundaries offers a greater resistance than that opposing slip within the crystals, tensile fractures will not be intercrystalline, even though the boundaries are weaker than the crystals themselves, so far as the direct pulling apart of the atoms is concerned.

If the process of "slip" is prevented, or the resistance to slip is increased sufficiently in some way, then intercrystalline fractures will result with little or no elongation, and a brittle material is indicated. Such inhibition of slip can be induced, for instance, by cold-work which, whatever the true nature of its effects be on the structure, certainly reduces the possibility of further deformation. Secondly, it may result from the addition to the metal of another substance which passes into solid solution. This latter process by distorting the space lattice is inimical to slip, with the result that as the hardness increases there is a general tendency for ductility to decrease, until finally a typically brittle metal with an intercrystalline fracture is produced.

Again, if fracture took place by the direct pulling apart of the atoms in the crystals themselves, obviously the actual fracture would be at right angles to the direction of the load; in other words, it would take place on the plane of minimum area where the stress was a maximum. This would mean that we should not get "cup and cone" and "wedge" fractures of any materials. We are thus led to the conclusions:—

1. That the crystal boundaries have not the strength usually associated with them, but that, owing to their irregularity of contour and atomic packing, they are strong in offering resistance to slip at the boundaries.

2. That fracture takes place in a ductile material by a process of slip within the crystals themselves.

3. That where such slip is prevented, an intercrystalline type of fracture results.

This relative weakness of the crystal boundaries, where the atoms are irregularly arranged, is important.

If a multi-crystalline material with a face-centred atomic arrangement be stressed in a given direction, "easy glide" will take place in each crystal until that orientation has been reached in which the atomic arrangement offers the greatest resistance to further movement under the action of this particular stress. (In this connection it should be noted that, even if "slip" takes place on an octahedral plane, the orientations of the parts remain unaltered. It is the "easy glide" movement on consecutive layers which produces changes of orientation.) In other words, the crystals will all tend to become orientated in the same direction, and, provided the stress were not such as to cause "slip," the material would to all intents become one large crystal, at least one can easily imagine that on the application of heat to bring about final adjustment, the material should exist in the form of one single crystal. If the stress were such as to cause slip, the structure would, of course, be completely broken down.

It is by the utilisation of this principle that Carpenter and Elam have produced their large single crystals of aluminium.

It will thus be seen that there is ample justification for the assumption that observations deduced from models hold good in the case of actual materials.

The next point to consider is what happens when "easy glide" takes place on two or more of the octahedral planes of a crystal. It has been demonstrated that such a movement of a number of layers of atoms on one octahedral plane produces a band of a primary twin. If, now, a similar twin band be formed on another of the octahedral planes, this latter band may intersect the first. Movement through the first band will then take place by "easy glide" in the most favourable direction on

its most favourably placed octahedral plane. The result will be a bar of a secondary twin at the intersection of the two primary twins.

It is interesting to determine the directions in which it is possible for these secondary bars to develop. They are parallel to the diagonals of the cube faces of the units of the crystal, and are therefore six in number.

We have now to consider the case where the movement is very much restricted, owing to interference on the part of neighbouring crystals. In this case, instead of the "easy glide" movement being completed in the primary twin bars, it will be restricted and arrested before it has reached the end of the "easy glide," but at a point where relief or reversal of the stress will cause the atoms to revert to their original positions. The result will be that on relief of the stress whilst the primary bands will undoubtedly revert to the original orientation, it is probable that, owing to the double movement which has taken place within it, the secondary bar will not. It is possible, of course, that some of these secondary bars may disappear entirely or in part, thus becoming broken, some parts of their lengths reverting to the original orientation, whilst others remain.

On repeating the cycle of stress the same thing will happen again, with the result that gradually a large number of bars will be formed. As the bars will not be of primary orientation with regard to the original crystal, there will be a disturbance of atomic arrangement at the boundaries. This must of necessity mean that the primary bands from which they have been formed are not able to revert entirely to their original positions; in other words, the crystal will become internally stressed. We thus, by continuing the reversal of stress, obtain crystals which: (1) Are made more rigid by the production of a large number of bars of another orientation; (2) develop planes of weakness due to bar boundaries at right angles to the applied stresses, since a tensile stress along a cube face diagonal produces a bar parallel to the other diagonal of the same cube face; (3) become internally stressed, due to the formation of the bars, the more bars formed the greater the amount of stress until eventually failure takes place, probably by actual separation of the atoms on the planes of weakness under the action of the direct stress applied. In this way we arrive at a fatigue failure.

It is now necessary to compare this new theory of the authors with the actually observed facts:—

(*a*) The markings on the crystals were undoubtedly of bar formation.

(*b*) The bars were definitely crystalline, but of a different orientation from that of the crystal in which they are formed.

(*c*) The bars were of fairly constant widths and varying lengths, and often appeared broken. Their directions were definite.

(*d*) In the material at the ends of the tubes, which had been annealed and hence showed twinning.

(1) The bars were never observed to pass through the twin boundary, and hence the change of orientation at this boundary had offered sufficient resistance under the stresses to which the tubes had been subjected.

(2) The fact that the orientation of the bars differed from both of those in the twinned crystal was demonstrated both by the etching properties and by the behaviour under oblique illumination. The difference of orientation was also shown by the fact that the bar at the twin boundary ceased abruptly and never fused into the orientation beyond.

(*e*) In no section examined was any indication of the primary bands from which the bars had been formed detected, the conclusion being that on the reversal of stress they had reverted to the original orientation, leaving the bar isolated.

(*f*) In nearly all the sections examined, bars appeared parallel to a twin boundary, that is, to an octahedral face.

(*g*) Bars do not appear in all of the crystals, the orientation clearly being too widely different from that of the ones showing the bars, and the stresses being only such as to cause bars in the most favourably orientated crystals.

(*h*) The fractures of all the tubes were exactly alike in type, and typical of fatigue fractures. It has been shown in the foregoing that breakdown either takes place by slip or by intercrystalline separation, and not by the separation of the atoms where they exist in regular arrangement. Quite obviously the fatigue fractures were not similar to those produced by slip, neither were they intercrystalline. Quite obviously, too, the stresses were not high enough to produce any ordinary fracture. We are led by a process of elimination to an unusual type of fracture, such as that arrived at from the present theory.

In view of the above, it is difficult to think that the theory now put forward by the authors to explain the fatigue failure is not essentially correct, especially having in mind the evidence brought forward for the "easy glide" movement, and it would appear that in face-centred cubic material the fatigue limit of stress is that which will just not cause any "easy glide" movement to become permanent.

JUGO-SLAV PUBLIC TENDER REGULATIONS.—H.M. Representative at Belgrade has forwarded a translation of that part of the Law on Government Accountancy of March 6, 1910, with amendments of June 27, 1921, in which are prescribed the regulations concerning the purchase of supplies by public tender by Government Departments of the Serb-Croat-Slovene Kingdom. The translation may be consulted by British firms interested on application to the Department of Overseas Trade, 35, Old Queen-street, London, S.W.1. (Reference, 12403/F.E.)

CATALOGUES.

Switches.—A list giving prices and particulars of iron-clad switch and fuse gear, sealing boxes and glands, is to hand from the Foster Engineering Company, Limited, Wimbledon, London, S.W.19.

Lubrication Accessories.—A list giving prices and particulars of oil tanks and cans, funnels, pumps for emptying barrels, &c., is to hand from Messrs. Joseph Kaye and Sons, Limited, 93, High Holborn, London, W.C.1.

Pipe Fittings for Petrol, &c.—A catalogue of a screw-down valve suitable for petrol, and another of flexible high-pressure hose for conveying petrol and oils has been received from Messrs. Hobdell, Way and Co., Limited, 45, Church-street, Minories, London, E.1.

Air Cooler.—Apparatus for air-cooling the windings of turbo-generators is described in a catalogue received from the Griscom-Russell Company, 90, West-street, New York, U.S.A. The air is circulated in a closed system and thus kept free from dust and moisture.

Coal-Cutting Machine.—A bar coal-cutting machine is described, and its application to various working conditions dealt with, in an 8-page catalogue to hand from Messrs. Cowlishaw-Walker and Co., Limited, Stoke-on-Trent. The machine can be operated electrically or by compressed air.

Packing and Sundries.—A useful catalogue of metallic and semi-metallic packings, special jointings, asbestos and rubber goods, non-conducting coverings, hose, belting, gauge glasses, &c., has reached us from the Beldam Packing and Rubber Company, Limited, 29, Gracechurch-street, London, E.C.3.

Oil Engines.—Messrs. Ruston and Hornsby, Limited, Lincoln, have sent us two interesting pamphlets relating to their cold-starting oil engines, the first giving a list of firms who have installed these engines and are willing to show them at work, and the second printing a number of testimonial letters from users.

Oil Engines.—The Anglo-Belgian Company, Limited, of Ghent, have issued a catalogue of land and marine oil engines with one to four cylinders and from 10 h.p. to 200 h.p. suitable for use with heavy fuel oil. Their agent for this country is Mr. Edgar W. Dorey, Norwich House, Southampton-street, London, W.C.1.

Artesian Well Boring.—A good general idea of the methods employed and the plant required for boring wells and pumping from them may be obtained from a six-page illustrated folder issued by Messrs. C. Isler and Co., Limited, Bear-lane, Southwark, London, S.E., who supply more detailed information on application.

Locomotive Headlight.—A full description and specification of a 500 watt electric headlight for use on locomotives, steam shovels, small craft, &c., is given in an eight-page catalogue received from the Westinghouse Electric and Manufacturing Company, East, Pittsburgh, Pa., U.S.A. It forms a complete unit, including a small steam turbine and electric generator, and weighs 240 lb.

Aero Engine.—A catalogue describing their "Lucifer" engine for aeroplanes has come to hand from the Bristol Aeroplane Company, Limited, Filton, Bristol. The engine is of the radial air-cooled type, rated at 100 b.h.p. and developing 118·5 b.h.p. at 1,760 r.p.m. on test. The consumption per brake horse-power hour is given as 0·6 pint of petrol and 0·04 pint of oil, and the weight as 350 lb., including propeller hub and bolts, oil cooler, hand starter and decompressor.

Roller Bearings.—Some 32 pages of useful and well-illustrated matter dealing with the application of tapered roller bearings to colliery rail trucks and also to the rollers of belt conveyors has been issued by the Timken Roller Bearing Company, Canton, Ohio, U.S.A., and a copy has reached us from British Timken, Limited, a company associated with Wolseley Motors, Limited, Adderley-park, Birmingham. Two rings of rollers on each wheel take the end thrusts in both directions and also carry the radial load.

Portable Tools.—Three catalogues dealing with portable tools actuated by compressed air or electric motors are to hand from the Consolidated Pneumatic Tool Company, Limited, 170, Piccadilly, London, W. 1. The first is a general list of 48 pages, giving illustrations and particulars of a large range of drills, hammers, grinding, and other machines, with the necessary accessories and attachments. The second catalogue deals with a hammer drill suitable for breaking up concrete, demolishing walls, digging clay, tamping, &c., and describes a range of tools suitable for these operations. The third catalogue is concerned with rock drills for mining and quarrying work. We are glad to note from these catalogues that attention is being given to the matter of reducing vibration to enhance the comfort of the operators.

Engines, Machinery and Plant.—A publication of particular interest has been issued by Messrs. Fullerton, Hodgart and Barclay, Limited, Paisley, in the form of a binding case containing copies of their recent sectional catalogues. These deal with winding engines; hydraulic plant, such as presses, pumps, accumulators, capstans and cargo handling gear; air compressors; evaporators, causticisers and soap coolers; steam engines and condensers; and iron castings. In each catalogue section there are numerous illustrations of actual products supplied by the firm in recent years for service at home and in various parts of the world, the examples being arranged and selected so as to show the most important types. Most of the examples are of large scale products, among which we may mention a winding engine capable of lifting 50,000 lb. at 4,000 ft. per minute, a compound pumping engine with 18-in. and 36-in. cylinders, mill engines up to 2,000 h.p., and hydraulic presses up to 1,000 tons capacity. Iron castings up to 50 tons are supplied by the firm, either rough or machined as required.

Electrical Measuring Instrument.—A form of combined bridge and potentiometer, designed by Professor D. Robertson, of the Merchant Venturers' Technical College, Bristol, for use in meter and instrument test rooms and laboratories, is illustrated and described in a four-page pamphlet to hand from Messrs. Crompton and Co., Limited, Chelmsford, who manufacture the instrument. The apparatus is intended to serve the double purpose of an ordinary four-gap, slide-wire bridge and a simple form of potentiometer, and while having a lower degree of accuracy than the firm's standard precision potentiometer and bridge, is claimed to be greatly superior to any of the other simple forms of similar apparatus now available. The pamphlet explains the method of using the apparatus for the measurement of voltage and the calibration of voltmeters, the measurement of current and ammeter calibration, and the measurement of low voltages and low resistances, the arrangement of the apparatus for these measurements being illustrated by means of diagrams. Prices are stated for the bridge and for the principal accessories.

Michell Bearings.—Messrs. Michell Bearings, Limited, 3, Central Buildings, Westminster, S.W.1, have issued a fourth edition of their Michell Bearings Book. The previous editions entered somewhat fully into the theory of lubrication and copies were supplied on request to many technical colleges for educational purposes. In view of the fact that the general character of Reynolds' theory is now universally known, it has not been considered necessary to include in the new issue of the book the theoretical matter which appeared in the former editions. The adequacy of the theory is well illustrated by the fact that the makers are able to give estimates of the heat generated in their bearings with the same confidence as the builders of a marine engine can predict its indicated horse-power. The agreement between experiment and rational calculation is extraordinarily close as was shown by Mr. R. O. Boswell in a letter which was published on page 11 of our issue of January 5, 1923. The new catalogue contains some striking illustrations of the carrying power of pivotted bearings both of the thrust and journal type. With the latter a load of 11 tons has been carried on a journal 12 in. diameter and 2 in. long. Another interesting illustration represents a large alternator with a shaft 16 in. in diameter at the bearing. By adopting the Michell principle a saving of 4 ft. 8 in. was effected at the overall length of the machine. The second portion of the catalogue contains a complete price list of standard bearings, parts and accessories.

COLD WORKING AND HARDNESS.—The New York journal *Mining and Metallurgy* refers to researches in the cold-rolling of various annealed metals—copper, iron, steel, aluminium, zinc, tin, &c.—without intermediate annealing, and the determination of hardness at various stages of rolling. The work was by Messrs. Rawdon and Mutchler, Washington, who found that during the initial stages of rolling the metal hardened rapidly. A maximum in hardness was reached at a relatively low deformation ratio (initial to final thickness) and a reversal occurred, the metal becoming softer as deformation was continued. In most cases the severely cold-rolled sheet was softer than the metal in its initial condition. All the metals tested gave the same general form of hardness-deformation curve. Annealing the cold-rolled strips at a low temperature (100 deg. C.) softened all of them appreciably. The general form of the hardness-deformation curve was, however, still maintained. All the cold-rolled strips of any series, after full annealing, gave the same scratch hardness, thus showing that the test results were independent of the thinness of the strips. During the hardening period in continuous cold working, deformation of the crystals by slipping occurred. In the severely cold-rolled specimens that showed appreciable softening, all evidence of the previously existing crystalline condition had been destroyed.

POTASH AND ALUMINA FROM LEUCITE.—The ordinary feldspars of igneous rocks, complex silicates of the alkali and alkaline earth and other metals have little value for the chemist, because the potash and alumina they contain cannot be extracted by acids, while fusion with alkalis would be too expensive. Leucite, one of these minerals, differing from the others by being soluble in acids, has often been tried as a new material, but so far with little success. Recently, however, Baron Blanc has been successful with the treatment of the leucite from an extinct volcano situated 30 miles north of Naples. This leucite contains 21 per cent. of potash (K_2O), 25·5 per cent. of alumina (Al_2O_3) and 55 per cent. of silica, and is generally exceptionally pure. The usual trouble in the decomposition of silicates with acids is that the silica is precipitated as a gelatinous mass which holds back the solution. Blanc, from a paper read before the Society of Chemical Industry by Professor J. W. Hinchley (*Chemistry and Industry*), crushes the rock, and extracts the granular leucite by keeping the acid circulating through the grains. When sulphuric acid is used, a good alum is thus obtained. There being not much demand for alum, unless of the highest purity and particularly free from iron, extraction with hydrochloric acid is also used. The hot solution is evaporated until the potassium chloride crystallises out, more gaseous hydrochloric acid is then passed into the remaining solution of aluminum chloride at 300 deg. C. or 350 deg. C. in a closed vessel, until the alumina falls out as hydrated aluminium chloride.